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PSYCHOLOGICAL EFFECTS OF SUSTAINED OPERATIONS IN A SIMULATED NBC ENVIRONMENT ON M1 TANK CREWS

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U S ARMY RESEARCH INSTITUTE
OF
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Human subjects participated in this study after giving their free and informed consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

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PSYCHOLOGICAL EFFECTS OF SUSTAINED OPERATIONS IN A SIMULATED NBC ENVIRONMENT ON M1 TANK CREWS

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ABSTRACT

Forty-eight M1 tank crewmen were tested in a temperate climate under conditions simulating 72-hour operations in an area contaminated with chemical agents. Over 50 per cent of the crewmen voluntarily withdrew from the test, and maximum unit endurance did not exceed 32 hours. Two problems were found to be related to endurance failure. Soldiers who withdrew reported more intense symptoms associated with respiratory distress than did those who remained in the test. In addition, soldiers who withdrew experienced greater cognitive difficulties. Near-term countermeasures, assessed in some of the test iterations, showed no significant endurance-extending effects. Alternative solutions based on the identified problems were proposed.

INTRODUCTION

Future wars may require 72-hour operations in environments contaminated by nuclear, biological or chemical (NBC) agents. The soldier's ability to withstand the added stress of the full NBC protective ensemble (MOPP 4) could be an important limiting factor. The most apparent problem with the ensemble is its relative impermeability, which impedes dry heat exchange and evaporative cooling. Much of the previous research, therefore, has been conducted under high ambient heat conditions. Increased risk of heat casualties and decreased physical work capacity have been well-documented[1-9], and decrements in perception and cognition have been observed[10,11].

Less is known about the effects of MOPP 4 in temperate climates. Performance difficulties, psychophysiological reactions, and attrition have been reported for military medical support personnel within two hours of work in 56-68 °F temperatures (dew point 38-40 °F).[12] However, such effects have not been consistently observed. No overt signs of psychological distress accompanied performance decrements in one medical support exercise[13], while immediate and severe psychological reactions were seen in another[14]. Moreover, the relevance of such findings has not been demonstrated for combined arms units. It is not known, for example, what problems may arise when the protective ensemble is used by isolated units during prolonged confinement in enclosed vehicles under conditions of sleep loss, food deprivation, and constrained water intake.

In the present study, tank crews were observed under temperate environmental conditions during a simulated 72-hour response to chemical attack. Both current NBC training, doctrine, and hardware as well as that which could be fielded in the near future were used in different test

iterations. A wide range of physiological, psychological, and performance measures were obtained.

This report will present psychological and performance findings from the test (psychophysiological, physiological, and general findings are reported elsewhere [15-17]). Three areas will be emphasized. First, MOPP 4 effects will be identified. General effects will be compared with those specifically related to endurance. Then, innovations used in some of the test iterations will be assessed to determine whether they served to enhance soldier performance and endurance. Finally, individual differences between the crew members will be considered to determine whether there are any measures that could predict which soldiers are likely to become incapacitated under NBC conditions. These findings will be related to those of three subsequent armor, artillery, and mechanized infantry field tests [18-21], where comparable data were collected. Together, these four tests -- conducted under widely varying operational and environmental conditions -- could identify basic NBC problems.

METHOD

Test Design

A between-subjects group design was used. Two different crews were tested in six successive iterations representing four test conditions. The first four iterations encompassed all the test conditions: baseline (B), hardware "fix" (H), training/doctrine "fix" (TD), and training/doctrine/hardware "fix" (TDH). The last two iterations repeated the baseline and training/doctrine/hardware conditions. The baseline condition

simulated the manner in which operations would currently be undertaken in a contaminated environment. The three "fix" conditions introduced innovations that could be fielded in the near-term. Each iteration consisted of a two-day training and orientation period followed by a 72-hour test.

Subjects

Twelve four-man tank crews (commander, gunner, driver, loader) participated in the test. Seven crews were from Ft. Knox, KY. Four of these were from A Co., 5th. Bn., 73rd. Armor Platoon and had worked together for varying periods of time. The other three crews had no previous experience together, and some members were recent Advanced Individual Training (AIT) course graduates. The additional five crews were from the Field Support Branch (Armor Section) of the US Army Combat Systems Test Activity (CSTA) at Aberdeen Proving Ground, MD. They had worked together in the past but did not constitute cohesive units.

Overall, median time with crew was 12 weeks. Distribution of rank was representative of armor units. Except for a lieutenant, crew members were enlisted and most often privates. Duty position in the test, however, did not always correspond to rank. A sergeant served as loader, and one SP4 served as tank commander. There was considerable variability among crewmembers in previous experience. Age ranged from 19 to 36 years (mean=23.5 yrs), time in service from four months to 12.5 years (mean=40.4 mos), and time in primary MOS from one month to nine years (mean=25.5 mos). The longest time crew members estimated they had previously spent in MOPP 4 ranged from zero to more than 15 hours (mean=4.0 hours). For sustained operations, the estimates ranged from zero to more than nine days (mean=3.0 days).

On the average, the crew members were 70.42 inches tall, weighed 179.00

pounds, and had scored 245 on their last PT test. Two-thirds of the crewmen were smokers.

Test Site and Apparatus

General. The test was conducted in an air-supported, 100 ft-radius dome located at Aberdeen Proving Ground, MD. Two stationary M1 tanks on elevated platforms together with a computer-operated Moving Target Simulator (MTS), a decontamination site, a field clinic, and structures housing test support personnel were located in the structure. Mean ambient dry bulb temperature in the dome was maintained within a range of 21.7-24.6 °C (71.4-76.3 °F) Mean turret temperatures ranged between 27.4-30.1 °C (81.3-86.2 °F). Mean ambient relative humidity was 45%, increasing to 57% in the turrets.

During the test, a scenario based on the fourth day of WWIII was enacted. The test vehicles were part of an armor platoon ordered to defend a hill for a period of three to five days, with the expectation of fighting under continuous chemical contamination. Nine attacks were scheduled, with lulls in between. Stationary targets were superimposed on a woodland scene projected on a wall of the dome, strobe lights and audio effects simulated artillery fire, and radio operators directed communications over "company" and "battalion" nets.

Test conditions. Standard materiel currently available under NBC conditions was used in the baseline and training/doctrine "fix" iterations. In the hardware and training/doctrine/hardware "fix" conditions, the following substitutions or additions were used: the XM43 Aviator's Protective Mask, which provided air cooling and improved vision; tube food, which could be consummed through a slit in the mask; enhanced/cooled drinking water, including iodine-compatible flavored water, NBC electrolyte solutions, and (in

the last iteration) commercial preparations; the Fluid Intake Suction Tube (FIST) Hydration System, which delivered water from the canteen to a drinking tube in the mask by a squeeze bulb rather than gravity feed; reclining seats for the commander, gunner, and loader; and a turret sleep hammock and driver seat sling.

During the training/doctrine and training/doctrine/hardware "fix" iterations, special procedures were instituted. Crew members were trained in and encouraged to follow a forced drinking regimen (one-half to three-quarters of a two-quart canteen every seven hours), a regimen of primarily isometric exercises designed for use in tanks, seven hour driver-loader rotation, and a sleep/rest schedule (20 hours at 100% alert followed by four hours at 50% alert). In addition, four one-hour NBC stress management training sessions were conducted with each crew (see Appendix A).

Psychological tests. Psychological tests were administered to assess relatively stable soldier attributes that could serve as predictors of response to MOPP 4 (single administration) and relatively labile states that were were expected to change over the course of the test (repeated administrations). A complete list of the psychological tests administered is presented in Appendix B. All tests were of the paper-and-pencil type, presented to the soldiers in bound booklets.

Most of the data described below were obtained from the following four questionnaires that were administered throughout the test. (1) Environmental Symptoms Questionnaire (ESQ).[22] This 60-item questionnaire was developed to assess a range of states associated with climatic extremes. Each item is rated on a six-point scale. On the basis of an abbreviated ESQ questionnaire administered in subsequent MOPP 4 tests[17-19], seven symptom factors were identified. These factors are used to organize the individual symptoms

described in this report. The factors are presented in the top panel of Appendix C. The items listed with each factor are those that contributed more to the variance of that factor than any of the other seven. (2) Clyde Mood Scale (CMS).[23] This 48-item questionnaire was developed to assess central nervous system function. Each item is rated on a four-point scale. The factor structure for this questionnaire is presented in the bottom panel of Appendix C. Columns in this table show ESQ and CMS items having comparable items. In this test, redundancy was decreased by eliminating ESQ items that were duplicated in the CMS. (3) Crew Atmosphere Scale (CAS). This 10-item USARIEM questionnaire measures individual crew members' perceptions of their crew as a unit. (4) Cognitive Strategies Questionnaire (CSQ). This 34-item questionnaire was designed at USARIEM to evaluate the effects of the stress management program developed for this test. Each stress management strategy is rated in one of four ways: "did not use", "used but did not help", "used and helped", or "does not apply".

Performance tests. Crew and individual measures of in-tank and extravehicular performance were obtained. In-tank tasks included: (1) Target engagement. Slides of Soviet vehicles (two T62s, two BMPs, or one of each) were projected for 50 seconds on the terrain backdrop. They were sized and positioned to appear at a range of 1 km. Target engagements (events initiated by trigger-pull) and "hits" were automatically recorded. Feedback was given for a "hit". (2) Encode/decode. The tank commander performed this task in response to information transmitted over the net. (3) Driver skill test. A Monte Carlo-type video game was performed by the driver on an hourly basis.

Extravehicular tasks included simulated refueling, ammunition resupply, target tracking (commander and gunner only), weapon assembly/disassembly, and vehicle/aircraft identification.

Procedure

Orientation/training period. Before participating in the test, the soldiers were briefed and medically screened. Each crewman signed a volunteer consent form with the understanding that he could terminate his participation in the test at any time for any reason without prejudice. Participation could also be terminated involuntarily. A crew member could be removed from the test if his core temperature reached 39.2 °C at rest or 39.5 °C (103 °F) during exertion, heart rate during any five minute period exceeded 160 bpm at rest or 180 bpm during exertion, or signs of illness or safety risk were observed by the medical monitors. In addition, he could be removed from the test in good health if his tank was declared combat ineffective (crew at half strength).

Over the course of the two days, the crew members were fitted with chemical protective gear (mask and hood, an overgarment, overboots, and gloves), trained in individual and crew tasks, and administered psychological (Appendix B, top) and physiological tests. In iterations involving training/doctrine "fixes", special instruction was provided.

Test period. On the morning of the first test day, crew members were weighed and instrumented for physiological monitoring. They then donned overboots and the protective overgarment over combat boots and the Combat Vehicle Crewman's (CVC) uniform. Prior to the start of the test, baseline values were obtained for those psychological tests that would be administered at invervals during the test (Appendix B, bottom). Start time was scheduled for 0900, but delays occurred. (For example, the first iteration -- one of the baseline conditions -- did not start until late afternoon.) At the start of the test, MOPP 4 was effected. Gloves and mask were donned, and all hatches in the tanks were closed. Fluids were continually available, but food

consumption was not possible except in the hardware "fix" iterations. Smoking was not permitted. Continual physiological, audio and video monitoring occurred throughout.

While in the tanks, crew members engaged in the various performance tests described above. Shortly before each resupply period, they were cued over the net to complete the psychological tests. Resupply periods occurred approximately four hours after the start of the test and at seven-hour intervals thereafter. Extravehicular performance tests occurred during resupply. Simulated decontamination was scheduled every 24 hours.

Whenever a crew member ended his participation in the test, he was medically cleared, deinstrumented, interviewed by USARIEM personnel, and given a final administration of the psychological tests.

Data analysis. Only the psychological tests administered during the orientation/training period (Appendix B, top) and three administrations of the other psychological tests (Appendix B, bottom) provided complete data on all 48 subjects. Values obtained from the remaining administrations were biased by the effects of attrition. Analyses of test effects were, therefore, based on the baseline administration (pre-test), the administration that occurred approximately four hours after the start of the test (first test), and the administration that occurred whenever a crew member left the test (termination). Two-way repeated measures analysis of variance (ANOVA) was used for most data.[24] Nonparametric data were submitted to Chi-Square analyses.

Performance was analyzed in a comparable but more limited manner. The small sample size permitted no more than descriptive statistics for a number of measures. Encoding/decoding data, for example, were only obtained from 12 tank commanders in all six iterations. In assessing the effects of the four

test conditions, the number decreased to 2-4 subjects/condition. Additional complications were presented by crew rotation, attrition, crew member replacement, and the assumption of two duty positions by one crew member.

Because attrition was such a predominant problem, analyses of psychological effects related to endurance were conducted. Preliminary analyses suggested that crewmen who withdrew from the test experienced similar problems regardless of actual endurance time. Therefore, all crew members were assigned to one of two post hoc groups: Casualties and Survivors. Casualties were soldiers who voluntarily withdrew from the test (there were no medical terminations); Survivors were soldiers who left involuntarily because their tank had been declared combat ineffective. This created two groups of approximately equal size and exposure to test conditions. The groups were used to analyze all psychological test data. Casualty-Survivor differences in performance, however, could not be identified. There was no one task that was both performed by all crew members and measured frequently enough to avoid substantial attrition effects.

RESULTS

General Test Effects

Symptoms. Nearly half of the 60 ESQ items showed statistically significant changes in mean intensity over the three administations analyzed. Table 1 shows these items, grouped by factor. It can be seen that crewmen experienced numerous and diverse bodily complaints. For all these symptoms, intensity increased over the course of the test. Three general patterns were seen. These are presented in Figure 1. Thermal symptoms showed the most

pronounced increase from pre-test to termination (+602%). Respiratory, musculoskeletal, neurological, and gastrointestinal symptoms followed a similar course and showed less of an increase from pre-test values (+312-510%). Fatigue symptoms increased the least (+228%).

Mood. Mood changes were even more prevalent than symptom changes. Table 2 presents those CMS items showing statistically significant changes over administrations. Thirty-one of the 48 CMS items, encompassing all six factors, are listed. All items showed that the soldiers experienced a general deterioration of mood. Two patterns, presented in Figure 2, were seen. Sleepiness, dizziness, and unhappiness items increased in intensity while aggressiveness, friendliness, and clear thinking items decreased. Changes from pre-test values were smaller than those seen for symptoms. Sleepiness items showed the greatest change, but this only represented a 46% increase.

Crew Atmosphere. Consistent with mood changes, there was a significant decrease in individual crew members' positive assessment of the crew as a whole.

Endurance. More than half of the crew members (54.2%) voluntarily withdrew before the 72-hour test was completed. Since some crew members simultaneously withdrew before the crew as a whole could be declared combat ineffective, Casualties were somewhat more numerous than Survivors. There was a significant difference ($p \leq 0.01$) in the duty position of Casualties. Eighty-three per cent of all gunners were Casualties compared with 50% commanders/drivers and 33% loaders. Gunners showed the shortest mean endurance time (10.57 hours), with individual times ranging from 3.17 to 23.00 hours. Figure 3 shows individual endurance times for all duty positions.

Performance. In contrast to the inadequate endurance demonstrated, few significant performance decrements were found. Measures showing significant

changes over time are presented in Table 3. All relate to target engagement. The number of targets engaged decreased while response time for both trigger pull and loading increased over the first three blocks of target presentation (each approximately three hours long, separated by varying periods of time). Figure 4 shows the mean per cent targets engaged by all crews. The greatest decrease occurred between the first and second time blocks (-32%). The smaller decrease between the second and third blocks as well as the seeming reversal in the fourth and fifth blocks (not shown) probably represent attrition effects rather than any general recovery. Figure 5 shows mean response times for trigger pull and loader arm measures. Again, the greatest change occurs between the first two time blocks (+42-44%), with minimal change thereafter. Slowed response, however, was not accompanied by diminished accuracy. Total targets hit are shown in Figure 6. Only four of the targets engaged (0.7%) were missed throughout the entire six test iterations.

Endurance-related Test Effects

Symptoms. While a broad range of symptoms showed increased intensity over the course of the test, only a small number showed significant Casualty-Survivor differences. These are presented in Table 4. Comparing these 12 symptoms with the ones described above, it can be seen that large increases in intensity may not necessarily predict endurance problems. Thermal symptoms showed the largest increases during the test but no significant differences between Casualties and Survivors. The mean intensity of "general sweatiness", in fact, was identical for both groups.

Casualty-Survivor symptom differences took two forms. Some symptoms ("malaise" and "restlessness") showed a different pattern of change over time for the two groups. This is shown in Figure 7. It can be seen that the

increase in intensity is much greater for Casulties than Survivors. The other ten symptoms, however, showed consistent group differences throughout. These symptoms are shown in Figure 8. "Backache", "muscle tightness", "leg/foot ache", "stomach ache", "gas", "shortness of breath", and "faintness" were all approximately two to three times more intense for Casualties than Survivors.

The one exception was "painful breathing", which had an overall mean intensity for Casualties that was 640% of that reported by Survivors. Even though this symptom showed the lowest intensity, it may have been critical to endurance. It was the only symptom of all those showing significant intensity differences across duty positions (Table 5) to parallel the distribution of Casualties across these positions (Figure 9). Both the intensity of "painful breathing" and per cent Casualties were greatest for gunners, at an intermediate level for commanders and drivers, and lowest for loaders.

Mood. Ten mood items were also significantly related to endurance. However, the overall Casualty-Survivor differences were smaller than those seen for symptoms and typically evolved more slowly over time. As Table 6 shows, only four of the ten showed consistent differences. These are shown in Figure 10. The three clear thinking items ("dependability", "clear thinking", and "efficiency") were 10-14% lower for Casualities than Survivors while "fear" was 16% higher. The remaining items are shown in Figures 11-13. For Survivors, there was little change or even a decrease in dizziness, aggressiveness, and unhappiness items while Casualties showed a marked increase by termination.

Cognitive strategies. Overall, Casualties found fewer cognitive strategies helpful for stress management than did Survivors ($p < 0.001$). Moreover, specific strategies showed significant Casualty-Survivor differences. When individual strategies were analyzed according to how many

soldiers categorized them as "helpful", "not helpful", or "did not use", eleven of the 34 strategies showed different distributions. These strategies are presented in Table 7. Figure 14 shows the number of soldiers who reported these strategies to be helpful. While having a positive attitude and a personal goal helped the most soldiers in both groups, the greatest Casualty-Survivor differences involved knowing how to control mask/respirator problems. This strategy helped more than three times as many Survivors as Casualties. Strategies involving relaxation techniques and not worrying about uncontrollable events were also important, helping two and a half times more Survivors than Casualties.

Performance. Casualty-Survivor performance differences could not be adequately determined through statistical analysis (see Method section). Some data, however, were compared to provide suggestions of the nature of performance-endurance relationships in MOPP 4. A comparison of endurance time and target engagement can be seen in Figure 15. Since target acquisition depends on both the gunner and commander, only data from those crews that had casualties in both duty postions are presented. It can be seen that crews having the longest commander endurance time also engaged the fewest targets in the first time block (78.10%), while the crew with the shortest commander endurance time engaged the most targets (100%). The gunner endurance curve approximates that seen for commanders. From this measure, it appears that limited endurance was associated with high performance output. Measures of performance speed showed a different relationship. This can be seen for trigger pull time (Figure 16). If anything, the shortest endurance times were associated with the slowest response times and the greatest variability in the first three-hour time block.

Test Condition Effects

Symptoms. The intensity of 17 symptoms showed statistically signficant dassnonrbnh among the four test conditions. These are shown in Table 8. A number of these symptoms showed a decrease in intensity in both conditions employing a hardware "fix", i.e., the hardware (H) and the training/doctrine/hardware (TDH) condition. These are shown in Figure 17. The greatest change from the baseline condition (B) occurred for "muscle tightness" (-61 or 72%) and other musculoskeletal symptoms (-61 or 64%). Fatigue symptoms decreased less, and "hunger" decreased the least (-37%). An additional group of symptoms (Table 8, Interactions) showed significant differences in response to the different test conditions between Casualties and Survivors. A subset of these symptoms also showed a pattern of symptom attenuation related to "fix" conditions (Figure 18). The relationship was apparent only for Casualties and was limited to the hardware (H) condition. Relative to the baseline condition (B), there were decreases in "irritablity" (-79%) and Respiratory Factor symptoms (-71%).

None of these symptoms, however, showed any relationship with endurance and only suggested some association with performance. Figure 19 shows mean Casualty endurance time by condition. As can be seen, endurance was greatest in the baseline condition (B) rather than in either of the conditions incorporating a hardware "fix" (H, TDH). Figure 20 shows trigger pull and loader arm times (right axis) as well as target engagement (left axis). These values (see Method section) are based on only 2-4 crew members/condition, include only the first time block, and do not represent statistically signficant differences. The two measures of response time suggest some effect of the hardware "fixes"; target engagement does not.

Mood. A larger number of mood items showed significant differences in

intensity across the four test conditions. These are presented in Table 9. Only one item ("boldness", Agressiveness Factor) showed a pattern suggesting a "fix" effect for all crew members (Figure 21). Compared with symptom changes from the baseline condition (B), the effect was small (-6 or 17%). Mood states showing Casualty-Survivor differences across conditions (Table 9, interactions) also included items that suggest "fix" effects. As with symptoms, these were limited to the Casualty group and showed decreases only in the hardware (H) condition. Figure 22 shows decreased itensity of sleepiness items (-35%) and increased intensity in friendliness items (+19%).

These mood items showed patterns similar to those seen for symptoms, and, therefore, offered no additional evidence for the beneficial effects of the fixes on endurance. In contrast, Casualty responses to clear thinking items (Table 9, interactions) -- which showed no relationship with the "fix" conditions -- showed a pattern that strongly resembles that seen for Casualty endurance times. This is presented in Figure 23. Casualties, on the average, reported attributes of clear thinking most in the baseline condition (B), less over the hardware (H) and training/doctrine conditions (TD), and least in the training/doctrine/hardware condition (TDH).

Cognitive strageties and Crew atmosphere. No significant differences were found across the four experimental conditions.

Predictors

Items from the battery administered during the training/orientation period showed trends, but only one significant predictor of endurance and the associated symptoms and moods was found. There appeared to be a U-shaped relationship between military experience and endurance. Significantly more Survivors had spent either 1-12 or more than 73 months in the Army, while

Casualties fell in the 13-72 month category ($p < 0.01$). All other items including age, height, weight, smoking, PT score, time in PMOS, prior MOPP 4 experience, prior sustained operations experience, time with present crew, most job-related attitudes, major life changes, marital status, anxiety, depression, perceived control, and sensation-seeking yielded no significant differences.

DISCUSSION

The results of this test showed that armor crews operating in MOPP 4 experienced adverse effects even under temperate climatic conditions. These effects were accompanied by extensive attrition. In contrast to previous NBC simulations conducted in temperate climates [12-14], over 50 per cent of the soldiers could not complete the test, and this number would, no doubt, have been higher had the remainder not been required to terminate their participation as their tanks were declared combat ineffective. The high attrition, combined with an extensive data collection effort, made it possible to identify problems associated with endurance failure that apply to groups rather than unique cases.

Heat was ruled out as a primary problem. There was no evidence of thermal stress from the core temperature data [16]. Moreover, thermal discomfort was not found to be related to endurance. While crewmen as a whole became increasingly troubled by the heat, this was true for both Casualties and Survivors. Two endurance-related problems of a different nature were isolated.

The first problem involved a small group of symptoms associated with

respiratory distress. Of these, "painful breathing" showed the greatest difference between Casualties and Survivors and also reflected the distribution of Casualties across duty positions. Only one other symptom ("shortness of breath") in this group was clearly respiratory in nature. However, there was reason to believe all the symptoms were related to respiration. This could not be verified in the present study. In the subsequent three MOPP 4 field tests [18-21], it was possible to submit pooled ESQ (short form) data to factor analysis. The right portion of Table 10 shows the factor found to account for the greatest amount of variance in the data. All symptoms that contribute to (load into) the factor are shown. It can seen that breathing symptoms play a prominent role ("painful breathing" = 0.77, "shortness of breath" = 0.73). The left portion shows the endurance-related symptoms in this test. By comparing the two sets of symptoms, it can be seen that all of the symptoms from this test (except two not included in the ESQ short form) are also represented in the "respiratory" factor. If these symptoms covaried in the field tests, they may well have done so in this test.

It is likely that soldiers, in response to actual or perceived respiratory difficulties, increased their breathing to the point where they experienced an array of symptoms. Such a hypothesis is viable even with the low respiratory symptom intensities reported in this test. Any intake of oxygen in excess of metabolic needs produces a decrease in carbon dioxide levels, changes the acid-base balance toward alkalosis, and has prevasive systemic effects. When such hyperventilation is minimal, increased air intake can take to form of excessive yawning or sighing or simply go unnoticed; the resulting symptoms, nevertheless, can be quite distressing [25-27]. Respirators can increase overbreathing [26,28] as can high ambient heat [29], exertion [25,30], and psychological stress [20,21]. In this test, fewer Casualties than Survivors were

able to control respirator problems. Gunners, who were disproportionately represented among Casualties, had particular problems. The M1 sight, it was learned, is configured so that proper use requires a pressure against the mask that disrupts air flow. In subsequent field tests, respirator problems were compounded by high heat and/or exertion. Breathing difficulties became more conspicuous, and the classic hyperventilation symptoms of tetany (muscle spasms) and paresthesia (numbness or tingling) showed significant Casualty-Survivor differences. The particular symptoms related to endurance varied somewhat across tests. However, a core of five symptoms was consistently seen across in all MOPP 4 iterations that did not involve "fixes". Three of these five symptoms described breathing difficulties.[21]

The second problem associated with endurance involved cognition. Casualties consistently rated themselves as less clear-thinking than Survivors, and ratings for the item "clear thinking" closely paralleled endurance times across conditions. Moreover, Casualties appeared to have fewer resources to counteract the problem. Fewer Casualties found cognitive strategies helpful under stress. Many of these strategies involved a restructuring by which counterproductive thinking is identified and reversed. It is likely that problems in thinking were not independent of the symptomatology described above. On the one hand, the breathing problems could have decreased mental acuity. Respiratory alkalosis is known to have adverse effects on the central nervous system.[32] On the other hand, confused thinking may have caused Casualties to overreact to minor bodily changes. In either case, the degree of cognitive change could be quite extreme. Panic reactions and claustraphobia were described by Casualties in exit interviews.

While two problems related to endurance were identified, this test offered little information on what measures could serve as predictors of

endurance failure and which of the countermeasures tested might be effective under NBC conditions. Only time in service gave some indication of who was likely to be a Casualty and who would be a Survivor. It was interesting, however, that trends toward greater anxiety and depression in Casualties were seen. These measures showed significant differences between the two groups in the field tests.[18-19] Since both of these mood disturbances have been shown to predict individuals likely to hyperventilate,[33-35] and depression has been associated with cognitive distortions[39], they hold promise in identifying vulnerable individuals. The findings on countermeasures also were limited. None of the "fixes" showed any effects that were related to endurance. If anything, there was an inverse relationship. Endurance time was greatest in the baseline condition, where no improvements were attempted. The Casualty-Survivor differences in cognitive strategies, which were taught during the training/doctrine "fix" conditions, reflected individual rather than test condition differences. However, the fact that cognitive strategies were related to endurance suggests that under improved training and testing conditions, they may prove to be beneficial in attenuating MOPP 4 effects.

The test also provided minimal information on performance. While few decrements were demonstrated, it cannot be concluded that performance was not a problem in MOPP 4. In many cases, the requirements for adequate statistical analysis were not met. In other cases, the selected tasks proved to be insensitive. Soldiers in exit interviews attributed their high "hit" rate, for example, to easy targets and inadvertent cueing by the projector rather than sustained proficiency. Moreover, the evidence provided by performance data that suggest a beneficial effect of the hardware "fixes" must be viewed with caution. The findings were based on a small number of subjects and no statistical analysis. The reasoning that the symptom and mood patterns

showing significant "fix" effects have operational importance because they follow performance patterns requires similar restraint.

Basic problems, predictors, and countermeasures that are related to performance remain to be identified. Two interrelated problems that might limit endurance have been proposed. These problems need to be systematically investigated under controlled conditions. If confirmed, a number of problem-specific countermeasures can be tested. Masks and respirators can be modified, techniques for breathing control taught [36-38], and training in cognitive restructuring [39] provided. Assessment of the two training "fixes" might be particularly profitable. They require no hardware changes, are currently available, and offer benefits under both NBC and conventional conditions. Hyperventilation has been historically associated with soldiers [40] and is, at present, considered to be a military problem [31].

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TABLE 1. GENERAL TEST EFFECTS: SYMPTOMS. ESQ items showing significant ANOVA main effects over three test administrations.

FACTOR	SYMPTOM	F	p
THERMAL	general sweatiness	71.71	0.000
	warmth	43.77	0.000
	foot sweatiness	27.32	0.000
	eye irritation	20.06	0.000
RESPIRATORY	muscle tightness	19.81	0.000
	headache	10.82	0.000
	muscle cramps	7.47	0.001
	stomach cramps	7.30	0.001
	numbness	6.57	0.01
	difficulty sleeping	6.17	0.01
	shortness of breath	3.86	0.05
MUSCULOSKELETAL	leg/foot ache	7.90	0.001
	arm/shoulder ache	6.75	0.01
FATIGUE	irritability	15.52	0.000
	boredom	11.81	0.000
	thirstiness	4.14	0.05
NEUROLOGICAL	lightheadedness	14.76	0.000
	backache	12.34	0.000
	faintness	7.18	0.001
	dim vision	3.86	0.05
GASTROINTESTINAL	poor coordination	10.82	0.000
	stomach ache	6.22	0.01

[1]no factor: burning/itching skin, feverishness, blurred vision, hearing loss, decreased urination, dry mouth, ringing ears

TABLE 2. GENERAL TEST EFFECTS: MOOD. CMS items showing significant ANOVA main effects over three test administrations.

FACTOR	MOOD ITEM	F	p
AGGRESSIVENESS	daringness	16.46	0.000
	boldness	13.12	0.000
	forcefulness	5.31	0.01
	boastfulness	3.85	0.05
	demandingness	3.15	0.05
SLEEPINESS	fatigue	16.13	0.000
	tiredness	10.36	0.000
	sleepiness	6.75	0.01
	drowsiness	4.93	0.01
FRIENDLINESS	friendliness	11.59	0.000
	kindness	10.38	0.000
	sociability	9.19	0.000
	politeness	9.13	0.000
	pleasantness	9.09	0.000
	considerateness	7.98	0.001
	playfulness	7.15	0.001
	goodnaturedness	5.87	0.01
	warmheartedness	5.05	0.01
	humorousness	4.69	0.01
CLEAR THINKING	concentration	11.21	0.000
	clear thinking	10.11	0.000
	dependability	7.76	0.001
	hard work	5.84	0.01
	alertness	5.50	0.01
	businesslikeness	5.20	0.01
	efficiency	3.22	0.05
	independence	3.10	0.05
DIZZINESS	dizziness	8.20	0.001
UNHAPPINESS	sadness	4.30	0.05
	depression	3.79	0.05
	unhappiness	3.48	0.05

TABLE 3. GENERAL TEST EFFECTS: PERFORMANCE. Significant effects over three-hour target presentation blocks.

TYPE OF MEASURE	TYPE OF ANALYSIS	VALUE	p
TARGET ENGAGEMENT	Chi-square	114.20	0.000
TRIGGER PULL TIME	Analysis of variance	12.42	0.001
LOADER ARM TIME	Analysis of variance	10.55	0.001

TABLE 4. ENDURANCE-RELATED EFFECTS: SYMPTOMS. Significant ANOVA Casualty-Survivor main effects and interactions under all test conditions.

FACTOR	SYMPTOM	F	p
	Main Effects		
NEUROLOGICAL	backache	11.55	0.001
	faintness	9.21	0.01
RESPIRATORY	shortness of breath	7.06	0.01
	painful breathing	6.04	0.05
	muscle tightness	5.79	0.05
MUSCULOSKELETAL	leg/foot ache	7.78	0.01
GASTROINTESTINAL	stomach ache	7.24	0.01
	gas	5.19	0.05
	Interactions with Time		
RESPIRATORY	malaise	8.74	0.01
FATIGUE	restlessness	3.75	0.05

[1]no factor (main effects): chilliness, ringing ears

TABLE 5. ENDURANCE-RELATED EFFECTS: SYMPTOMS & DUTY POSITION. Significant ANOVA effects across duty positions under all test conditions.

FACTOR	SYMPTOM	F	p
RESPIRATORY	numbness	4.45	0.01
	difficulty sleeping	3.85	0.01
	painful breathing	3.07	0.05
	stomach cramps	2.99	0.05
MUSCULOSKELETAL	leg/foot ache	4.10	0.01
FATIGUE	boredom	3.72	0.01
NEUROLOGICAL	backache	3.26	0.05
	dim vision	3.16	0.05

[1]No factor: appetite loss, chilliness, diarrhea

TABLE 6. ENDURANCE-RELATED EFFECTS: MOOD. Significant ANOVA main effects and interactions under all test conditions.

FACTOR	MOOD	F	p
	Main Effects		
CLEAR THINKING	dependability	6.45	0.01
	clear thinking	4.20	0.05
	efficiency	3.85	0.05
UNHAPPINESS	fear	4.34	0.05
	Interactions with Time		
DIZZINESS	dizziness	7.22	0.001
	nausea	4.47	0.01
	shakiness	4.12	0.01
UNHAPPINESS	troubledness	6.55	0.01
AGGRESSIVENESS	rudeness	4.65	0.01
	recklessness	3.32	0.05

TABLE 7. ENDURANCE-RELATED EFFECTS: COGNITIVE STRATEGIES. Significant Chi-Square differences between Casualties and Survivors under all test conditions.

STRATEGY	x^2	p
Remembered the positive aspects of self/situation	12.03	0.001
Did not worry about uncontrollable events	9.55	0.01
Had a personal goal to achieve	9.36	0.01
Could control problems with mask and respirator	6.48	0.01
Was able to predict own resonses	6.11	0.01
Acted even when unmotivated	6.04	0.01
Used imagery/muscle control to calm down	4.77	0.05
Turned stress into a challange	4.75	0.05
Respected individual standards	4.75	0.05
Did not take responsibility for uncontrollable events	4.62	0.05
Kept going to keep the crew together	5.58	0.05

TABLE 8. TEST CONDITION EFFECTS: SYMPTOMS. Significant ANOVA main effects and interactions across four test conditions.

FACTOR	SYMPTOM	F	p
	Main Effects		
FATIGUE	restlessness	5.61	0.001
	boredom	3.97	0.01
RESPIRATORY	muscle tightness	4.79	0.01
	shortness of breath	2.99	0.05
THERMAL	foot sweatiness	4.47	0.01
MUSCULOSKELETAL	leg/foot ache	2.93	0.05
	arm/shoulder ache	2.69	0.05
	Casualty-Survivor Interactions		
RESPIRATORY	malaise	6.59	0.01
	headache	3.19	0.05
	stomach cramps	3.13	0.05
	difficulty breathing	2.91	0.05
MUSCULOSKELETAL	weakness	3.09	0.05
FATIGUE	irritability	2.92	0.05

[1]no factor (main effects): hunger; no factor (interactions): feverishness, burning/itchy skin, thirst

TABLE 9. TEST CONDITION EFFECTS: MOOD. Significant ANOVA main effects and interactions across four test conditions.

FACTOR	MOOD	F	p
	Main Effects		
FRIENDLINESS	politeness	3.74	0.01
	considerateness	2.68	0.05
AGGRESSIVENESS	boldness	3.54	0.05
CLEAR THINKING	clear thinking	3.39	0.05
	efficiency	3.14	0.05
	businesslikeness	3.13	0.05
	Casualty-Survivor Interactions		
AGGRESSIVENESS	forcefulness	6.50	0.000
	quarrelsomeness	4.75	0.01
	rudeness	4.65	0.01
	demandingness	2.72	0.05
CLEAR THINKING	grouchiness	6.27	0.001
	independence	5.73	0.001
	concentration	5.38	0.01
	alertness	3.31	0.05
UNHAPPINESS	downheartedness	3.75	0.01
FRIENDLINESS	sociability	3.52	0.05
	impulsiveness	3.22	0.05
	goodnaturedness	2.83	0.05
SLEEPINESS	tiredness	3.34	0.05
	fatigue	3.05	0.05
	sleepiness	2.79	0.05

TABLE 10. COMPARISON OF ENDURANCE-RELATED[1] SYMPTOMS FROM THIS TEST WITH SYMPTOMS SHOWN TO COVARY IN SUBSEQUENT MOPP 4 FIELD TESTS[2].

PRESENT TEST	THREE FIELD TESTS	
ENDURANCE-RELATED SYMPTOMS	ESQ FACTOR 1 SYMPTOMS[3]	LOADING
	muscle cramps	0.78
PAINFUL BREATHING	painful breathing	0.77
SHORTNESS OF BREATH	shortness of breath	0.73
MUSCLE TIGHTNESS	muscle tightness	0.70
	stomach cramps	0.67
	poor concentration	0.61
MALAISE	malaise	0.56
	headache	0.53
	difficulty sleeping	0.46
	weakness	0.45
	eye irritation	0.44
	numbness	0.43
	appetite loss	0.44
RESTLESSNESS	restlessness	0.39
LEG/FOOT ACHE	leg/foot ache	0.38
GAS	gas	0.38
	tiredness	0.37
STOMACH ACHE	stomach ache	0.35
	sleepiness	0.35
NAUSEA	nausea	0.32
	poor coordination	0.31
	lightheadedness	0.28
BACKACHE	backache	0.27
IRRITABILITY	irritability	0.26
	nose bleeds	0.26
FAINTNESS	faintness	0.25

[1] CMS items "nausea" and "irritability" (standard ESQ items) and ESQ items

[2] see references 18-20

[3] One of seven factors (see Appendix C) identified on the basis of pooled data from three MOPP 4 field tests

FIGURE 1. GENERAL TEST EFFECTS
Symptom Intensity Patterns

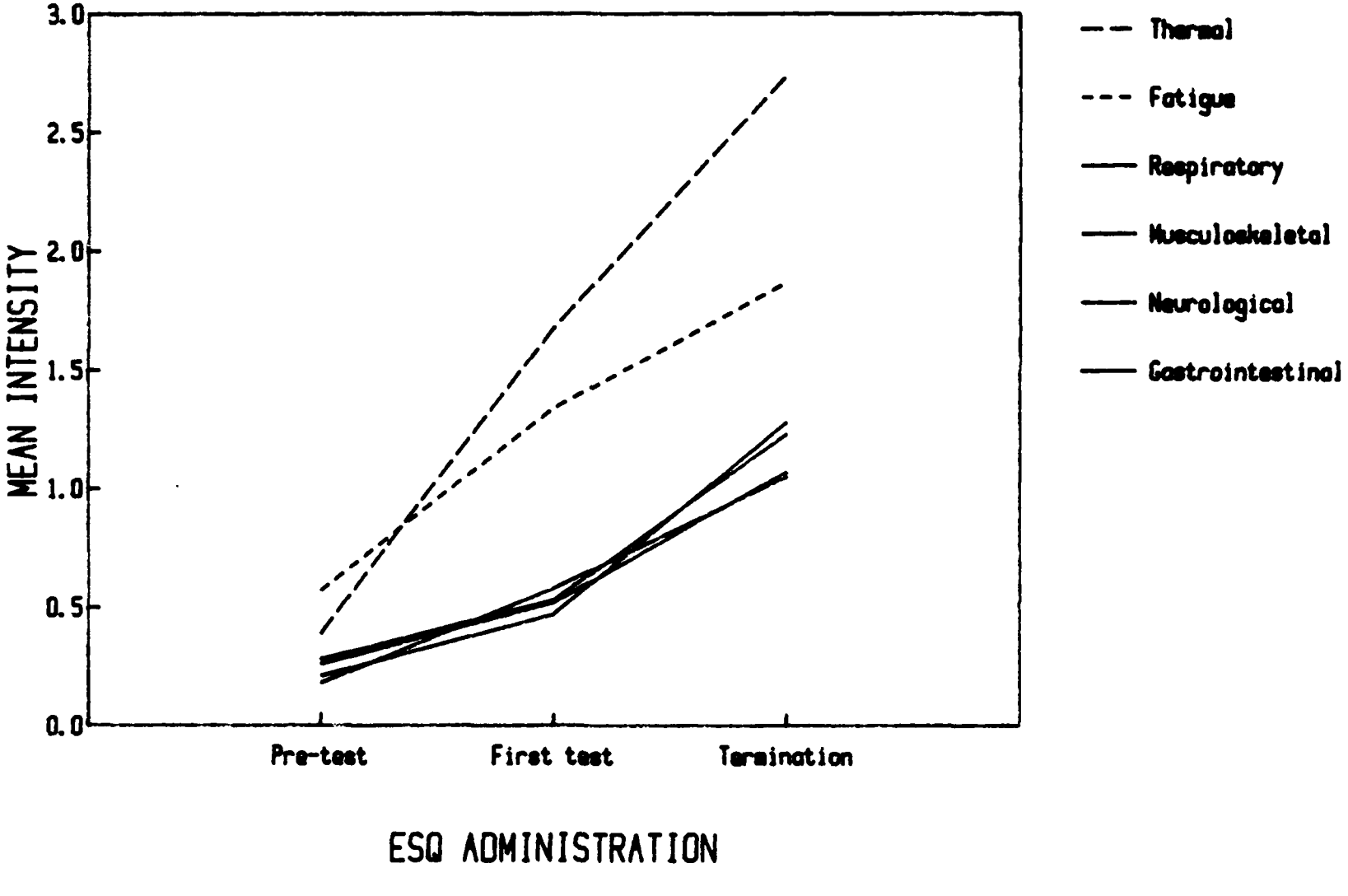


FIGURE 2. GENERAL TEST EFFECTS
Mood Intensity Patterns

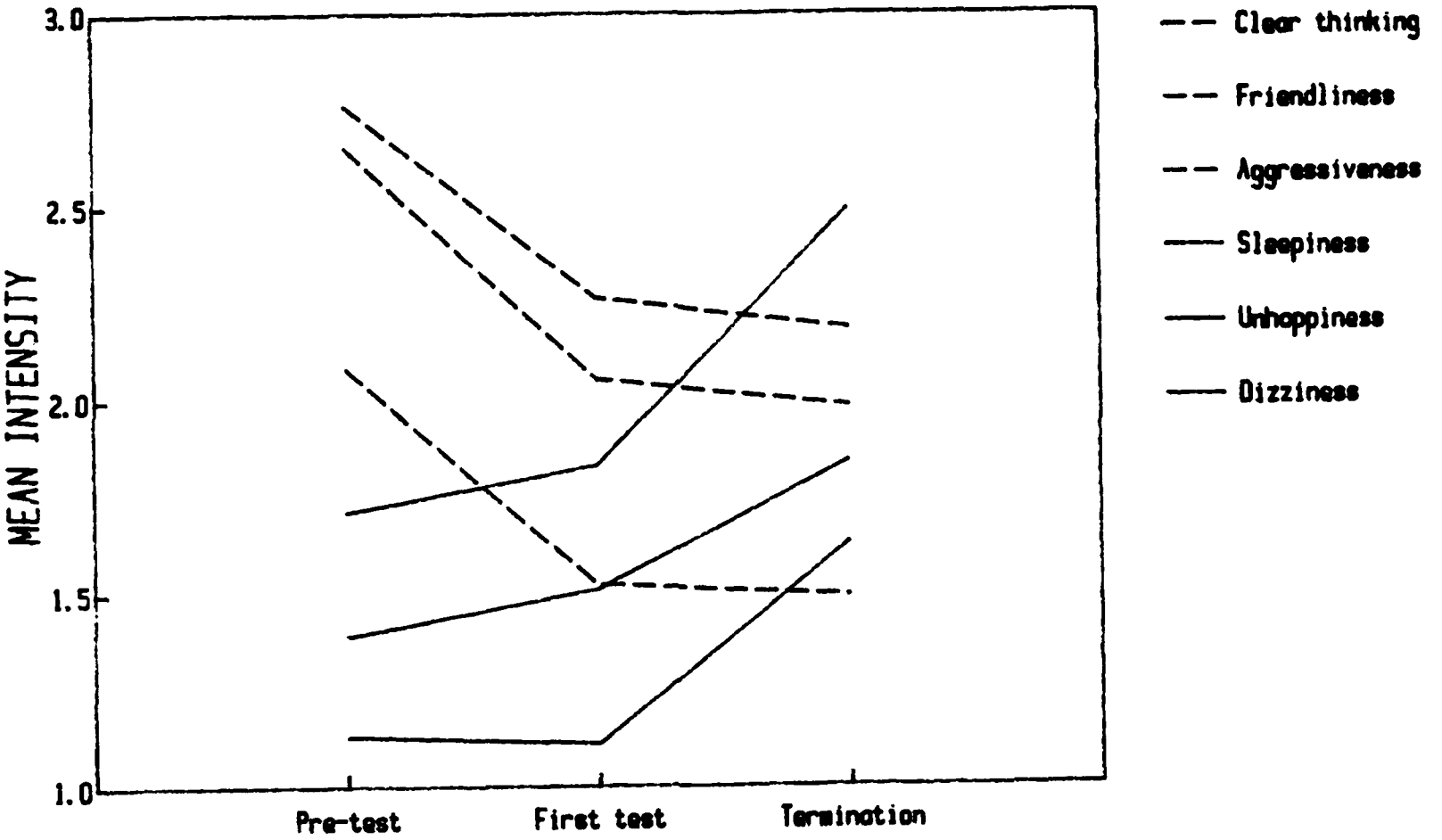


FIGURE 3. GENERAL TEST EFFECTS
Casualty Endurance Times by Duty Position

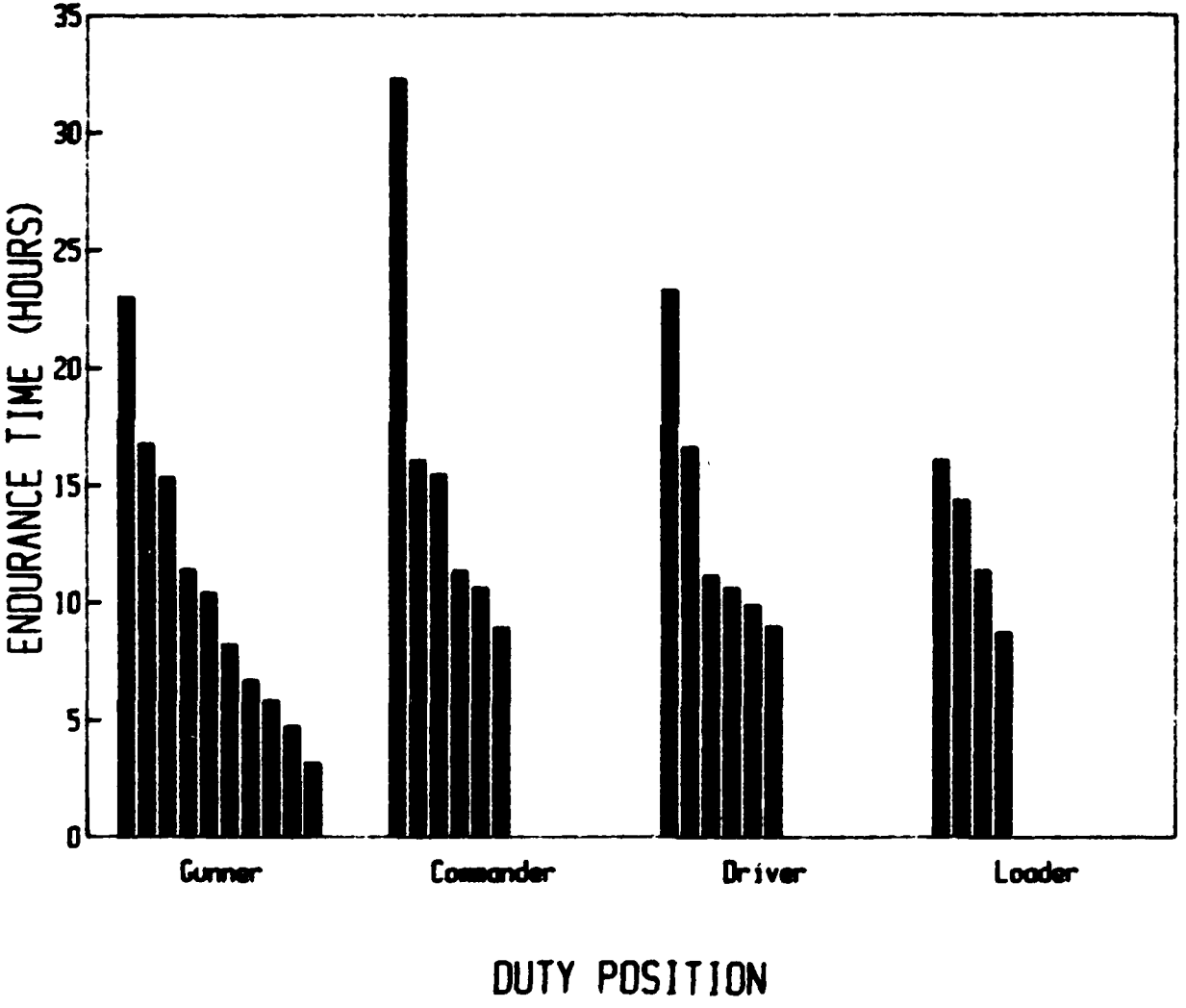


FIGURE 4. GENERAL TEST EFFECTS
Target Engagement

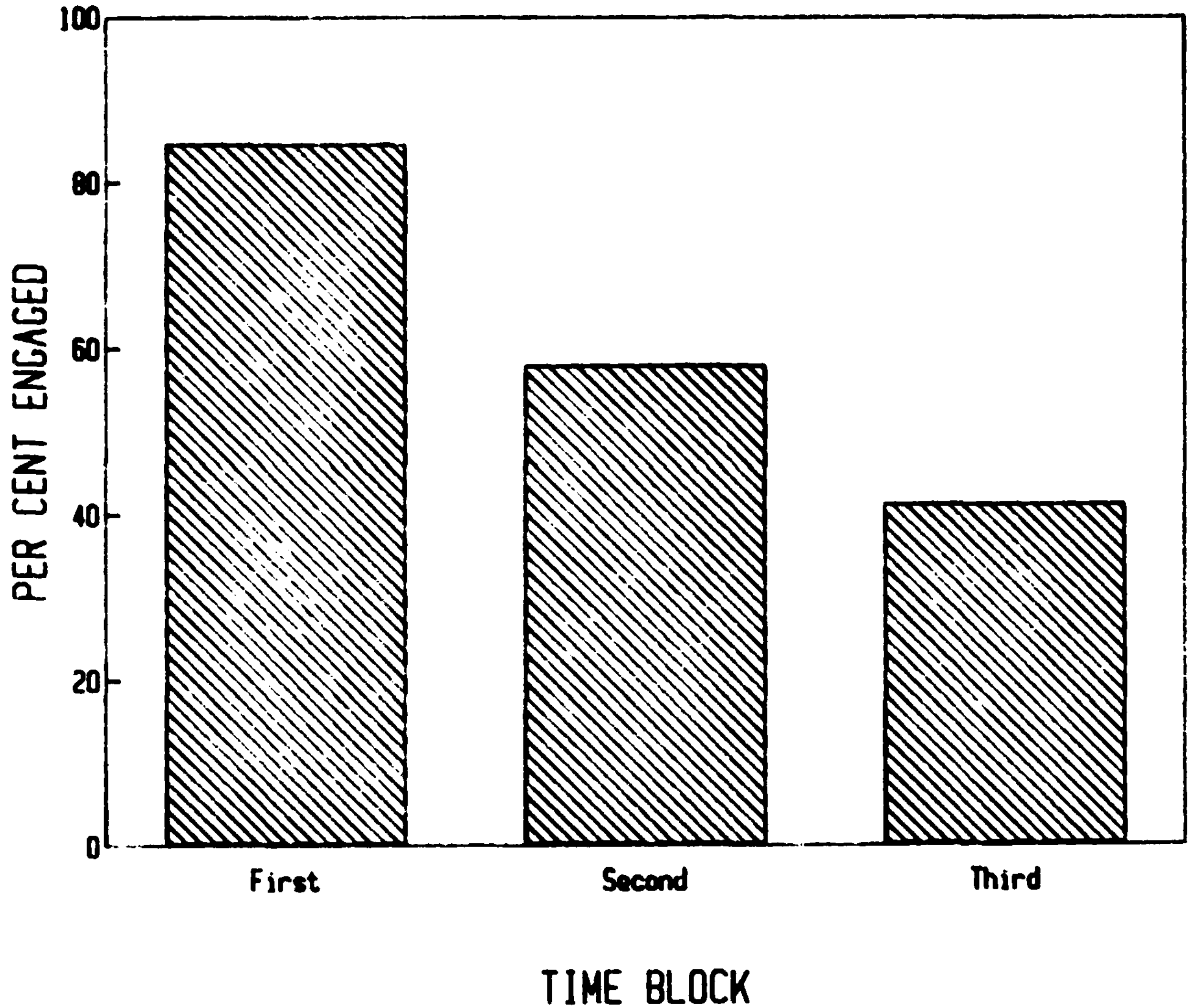


FIGURE 5. GENERAL TEST EFFECTS
Loader and Gunner Response Time

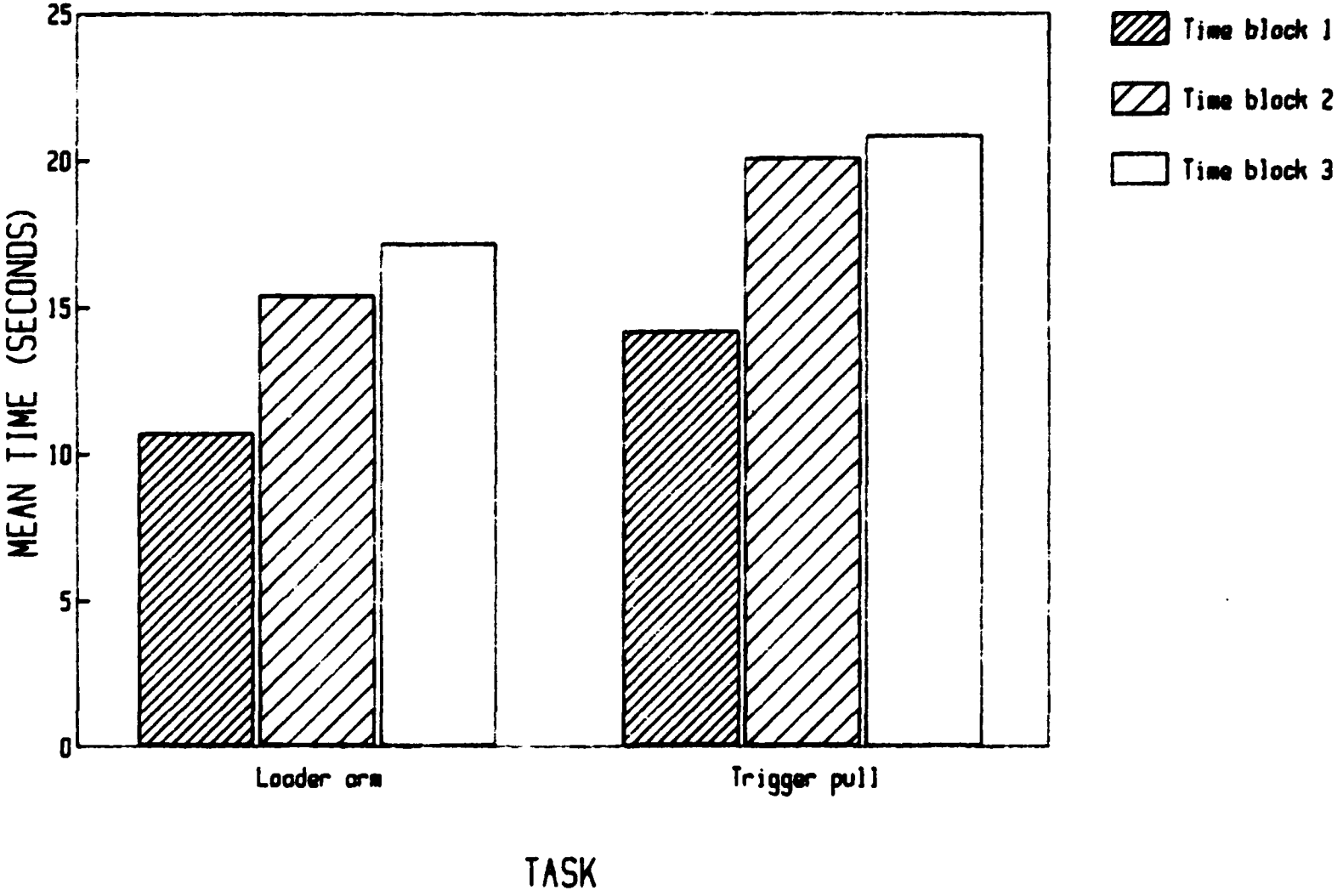


FIGURE 6. GENERAL TEST EFFECTS
Total Targets Hit

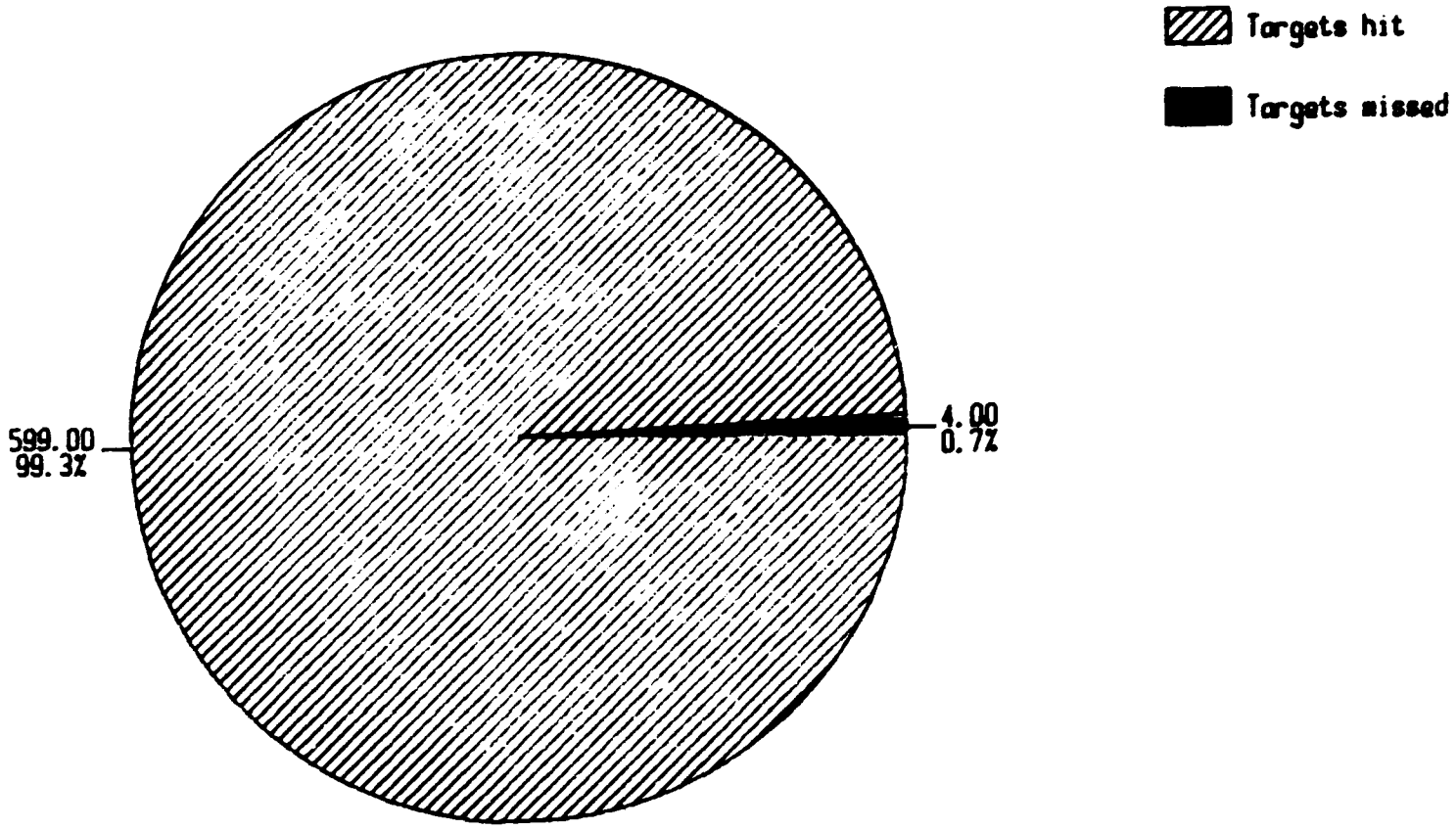


FIGURE 7. ENDURANCE-RELATED EFFECTS
Symptoms Interacting with Time

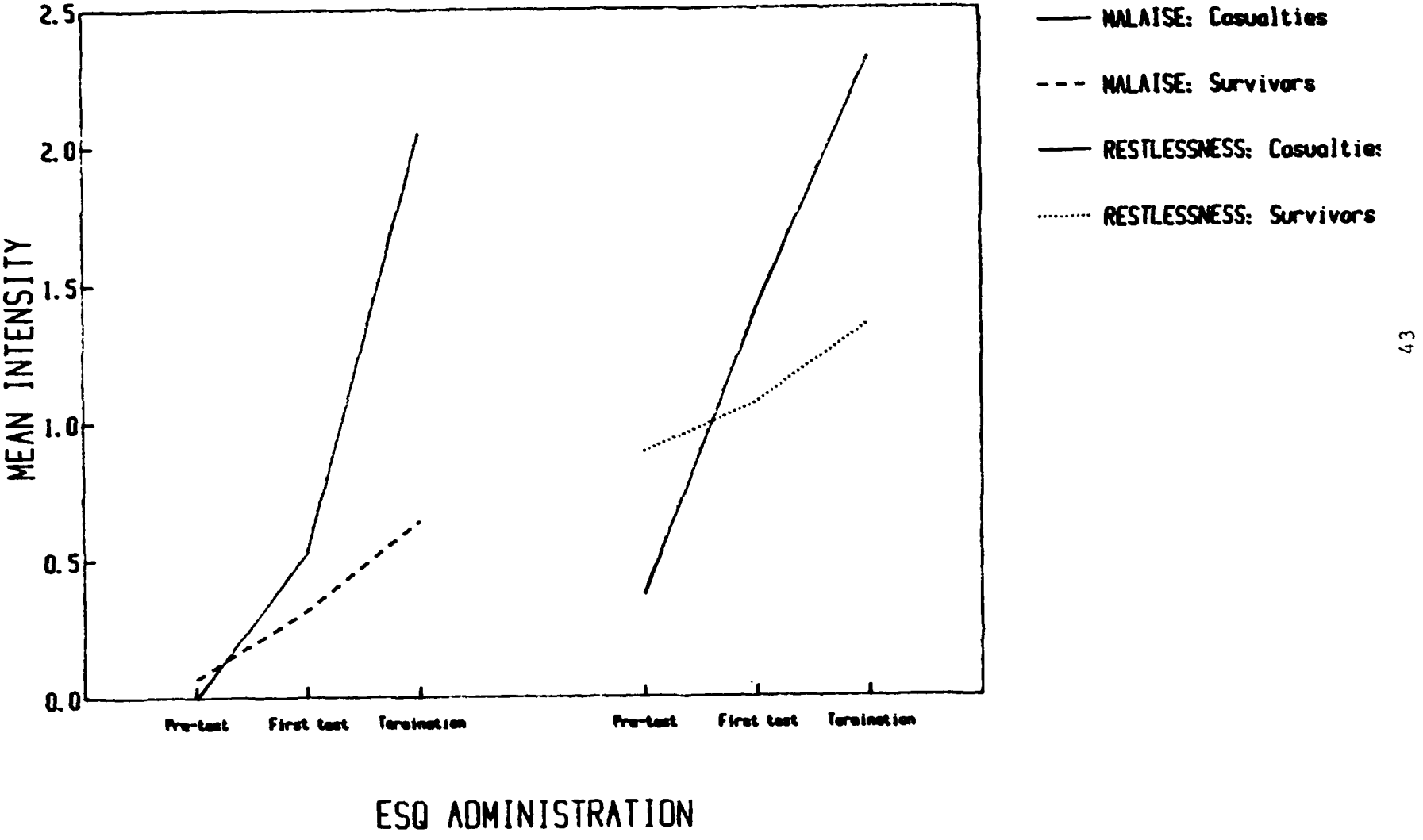


FIGURE 8. ENDURANCE-RELATED EFFECTS
Consistent Symptoms

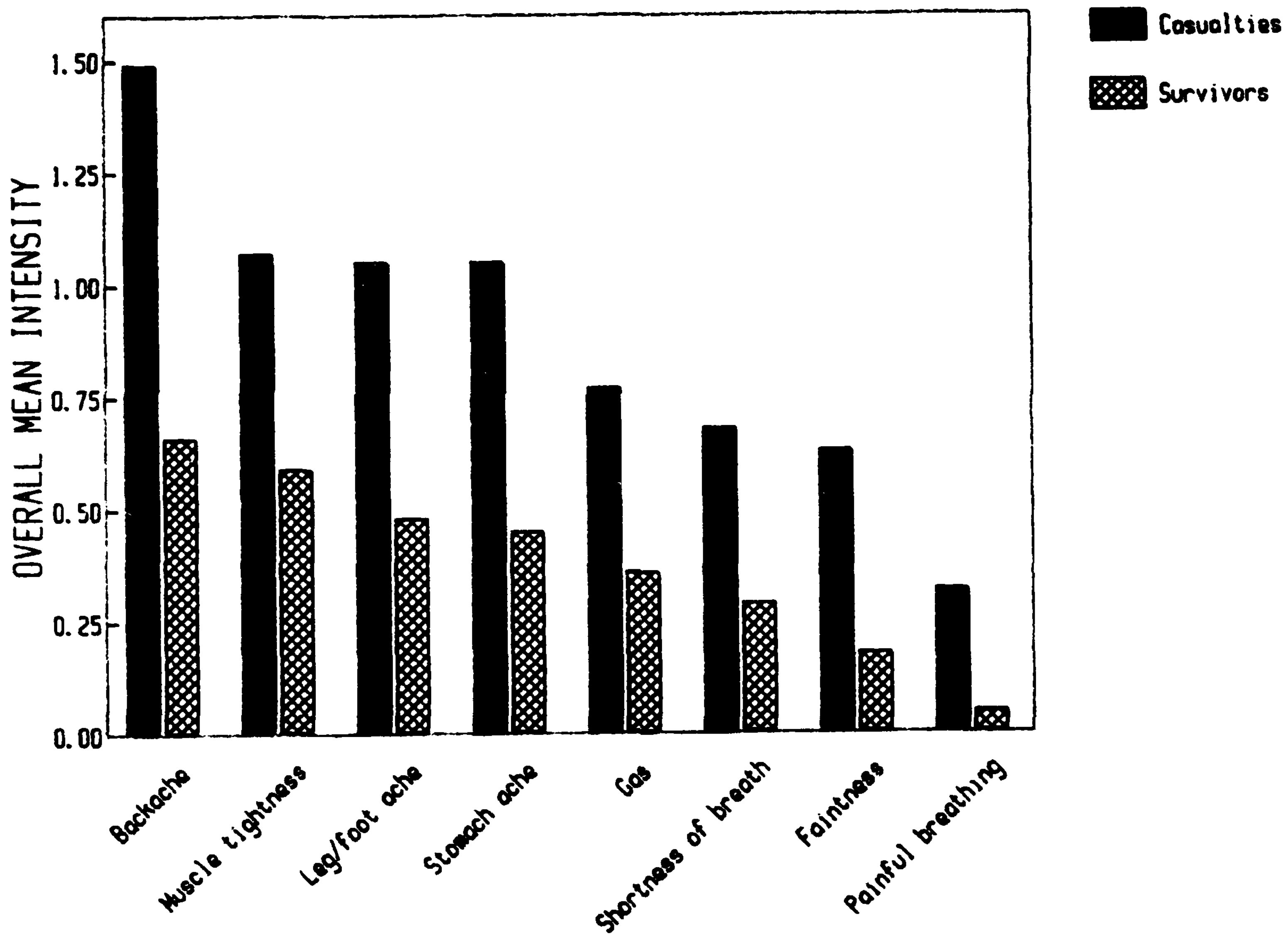


FIGURE 9. ENDURANCE-RELATED EFFECTS
Symptoms, Duty Position & Casualties

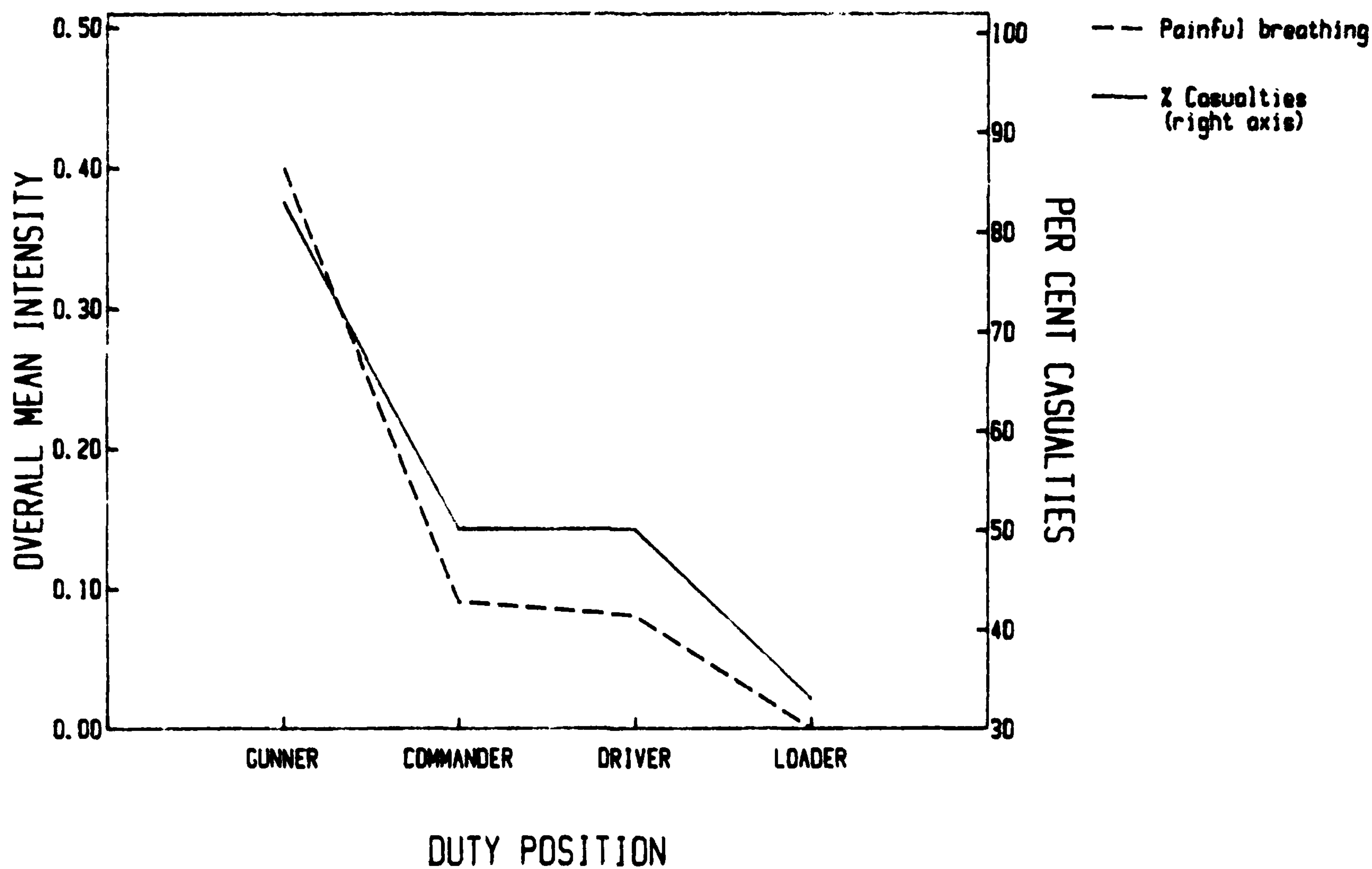


FIGURE 10. ENDURANCE-RELATED EFFECTS
Consistent Moods

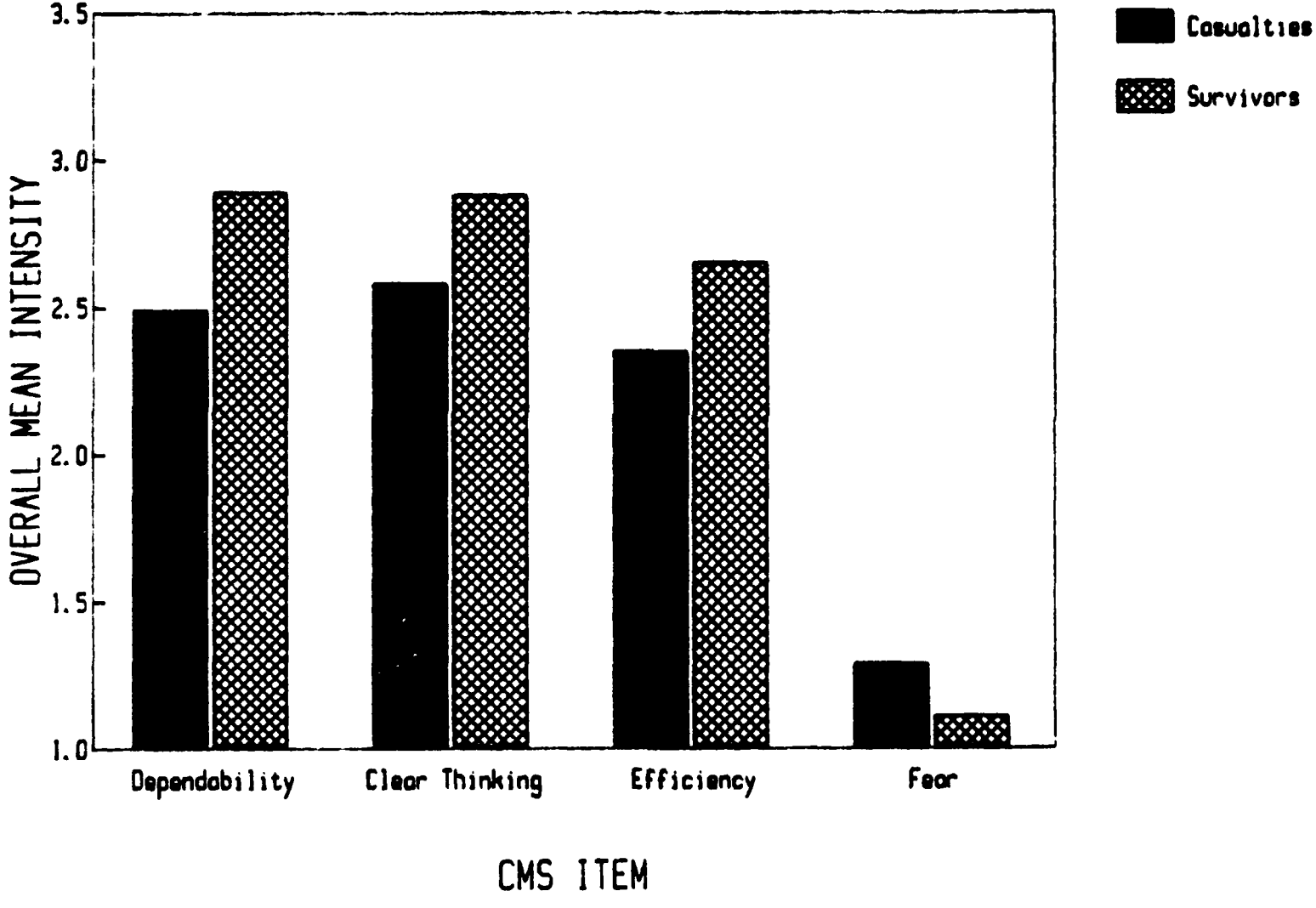


FIGURE 11. ENDURANCE-RELATED EFFECTS
Moods Interacting with Time: Dizziness

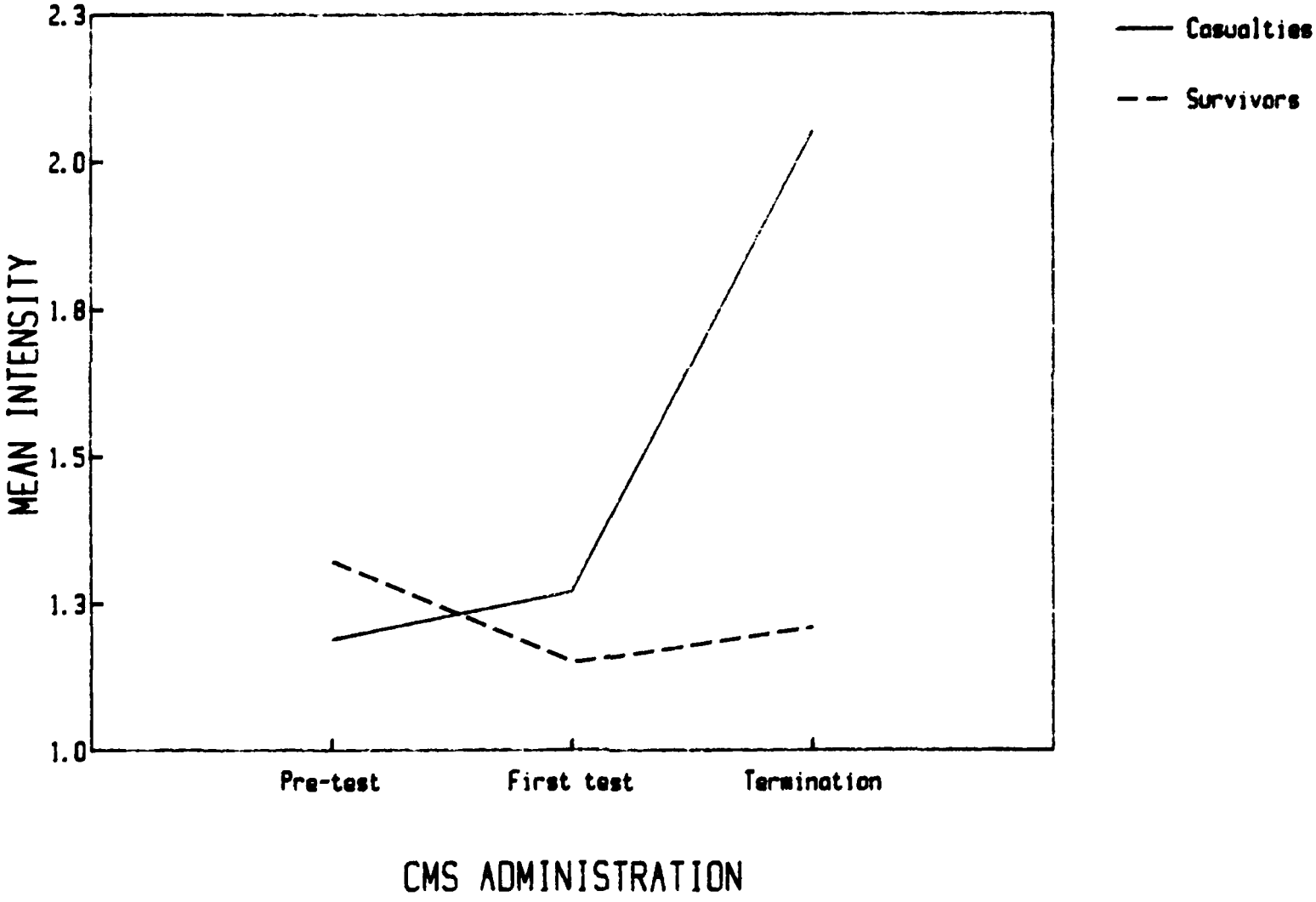


FIGURE 12. ENDURANCE-RELATED EFFECTS
Moods Interacting with Time: Aggressiveness

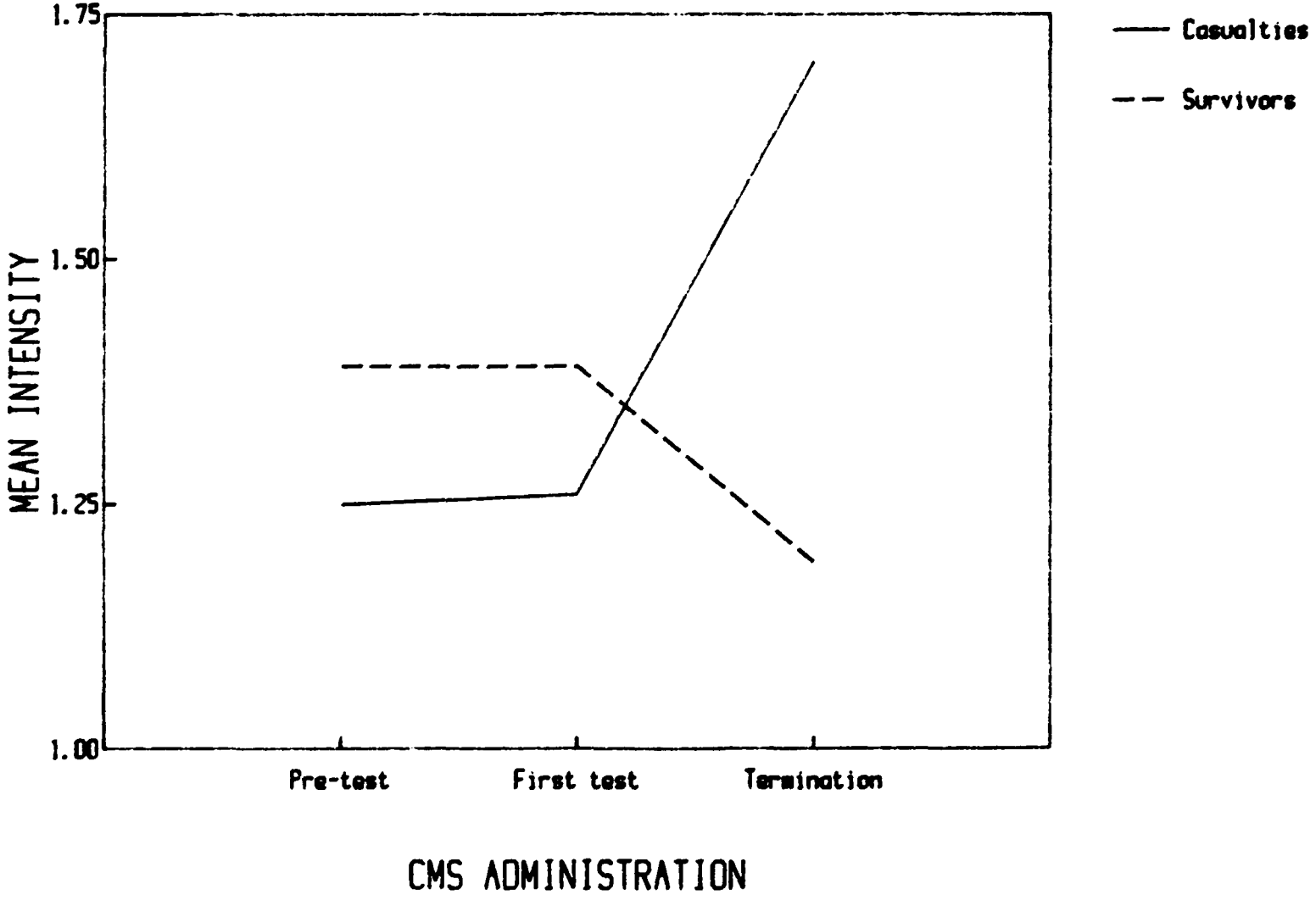


FIGURE 13. ENDURANCE-RELATED EFFECTS
Moods Interacting with Time: Unhappiness

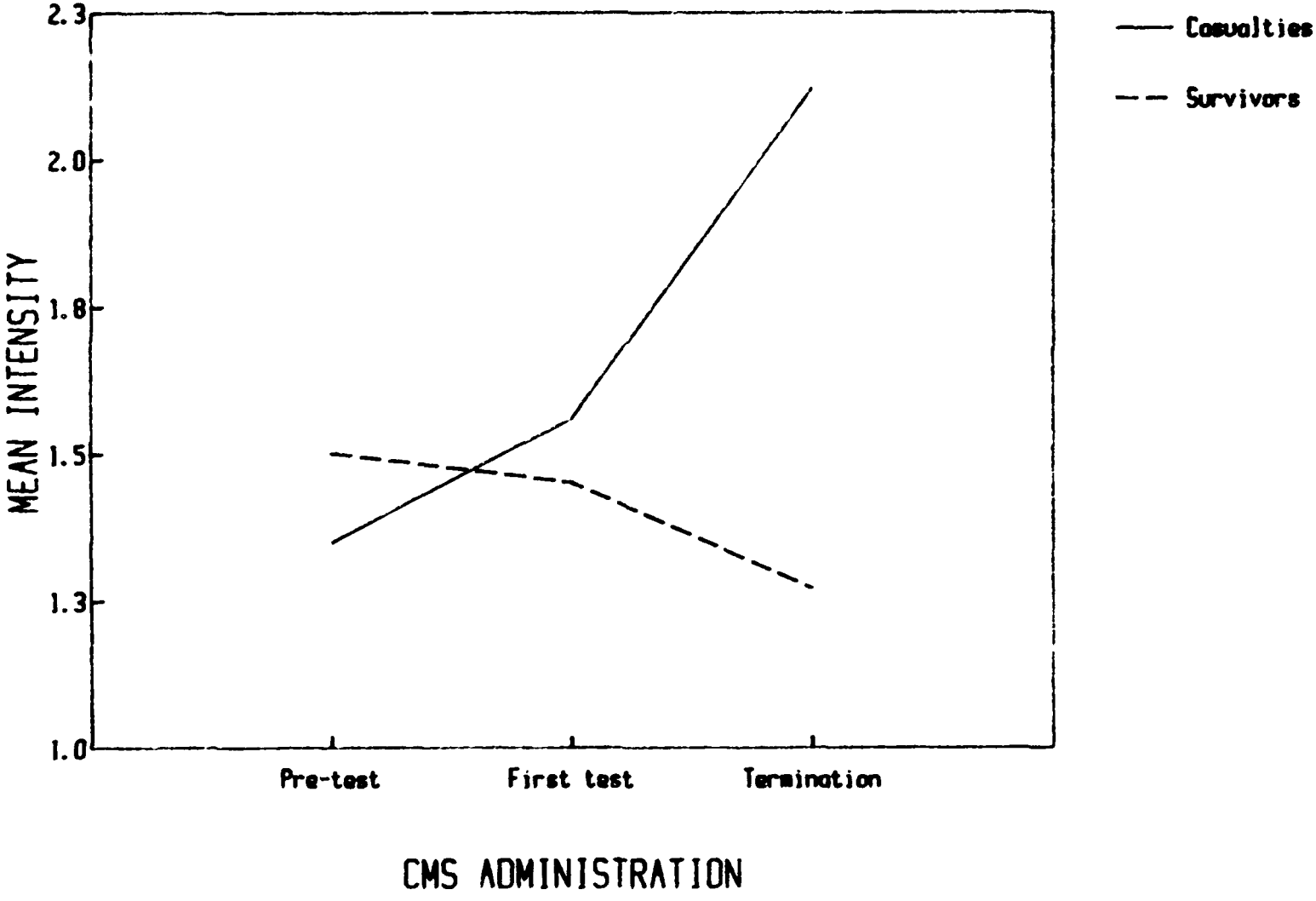


FIGURE 14. ENDURANCE-RELATED EFFECTS
Cognitive Strategies

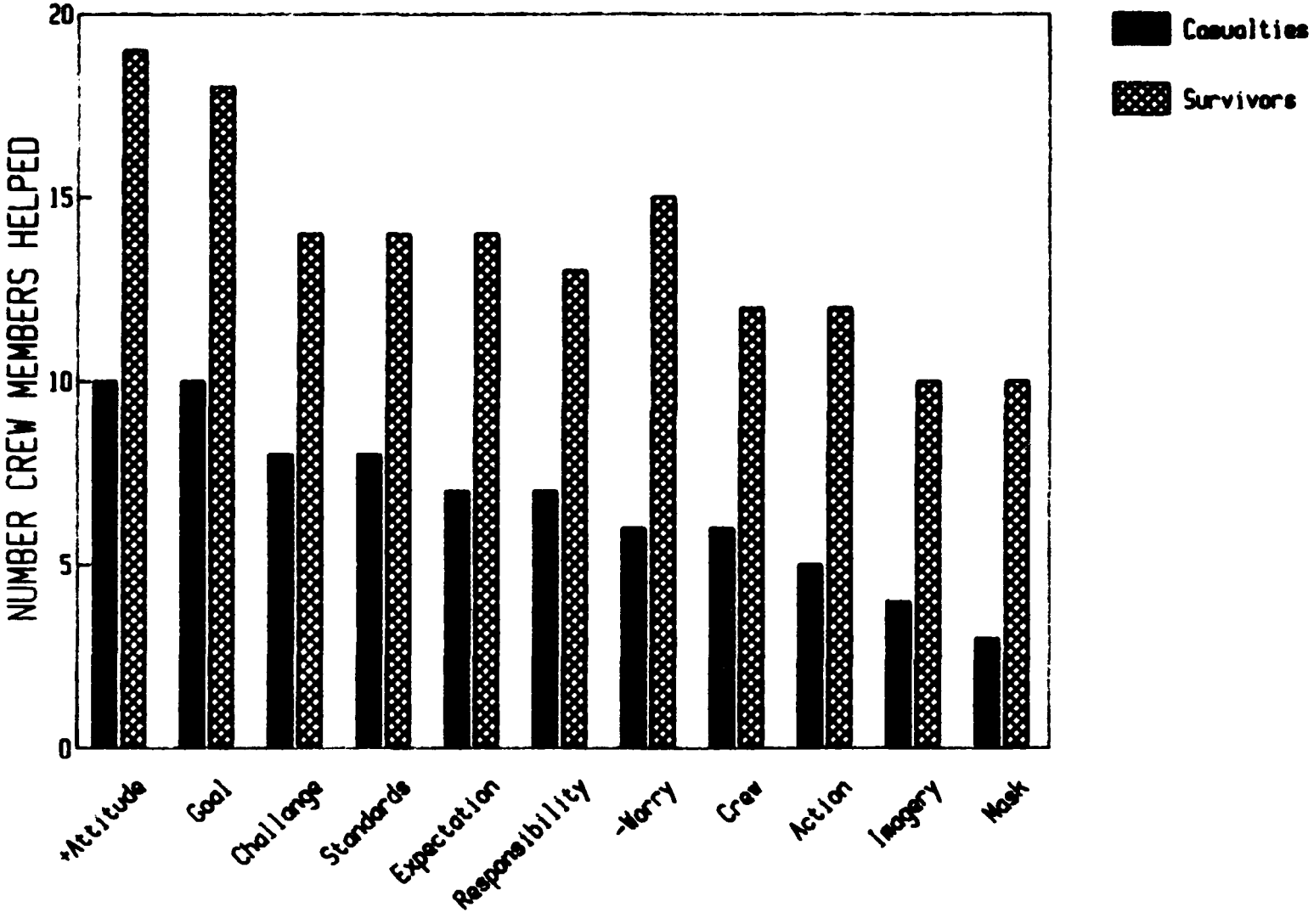


FIGURE 15. ENDURANCE-RELATED EFFECTS
Target Engagement & Endurance

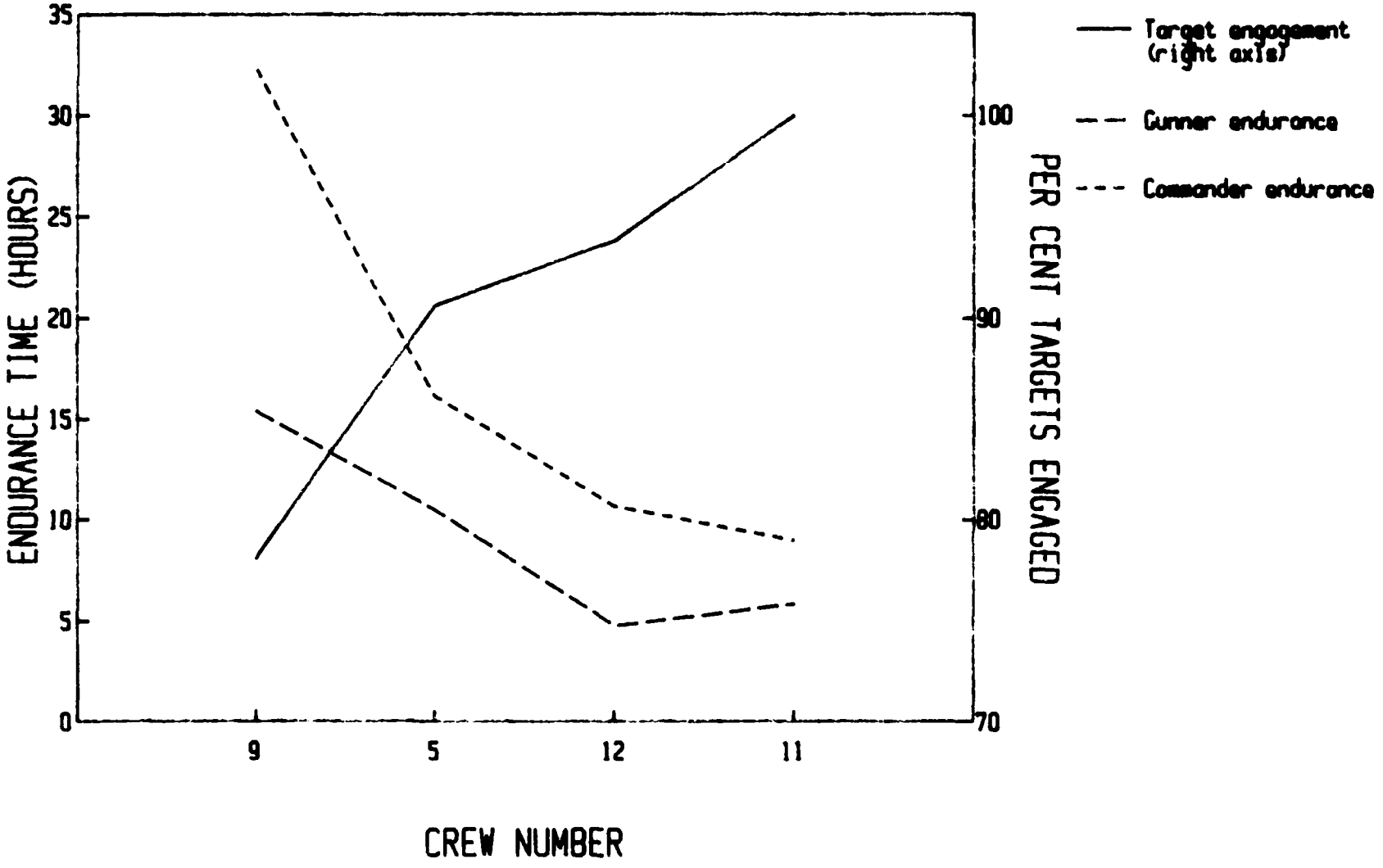


FIGURE 16. ENDURANCE-RELATED EFFECTS
Trigger Pull & Endurance

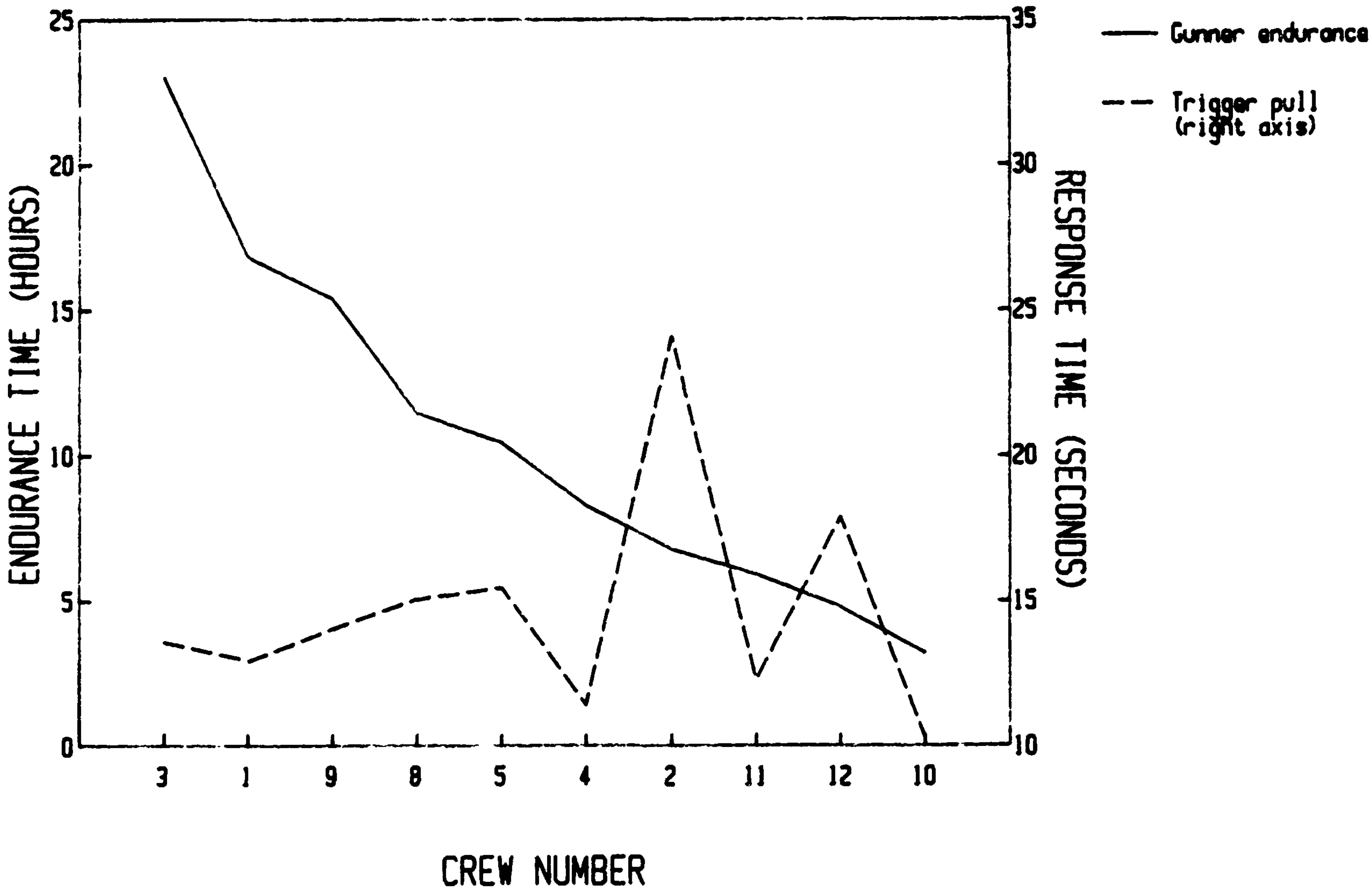


FIGURE 17. TEST CONDITION EFFECTS
Symptom Patterns: All Crew Memebers

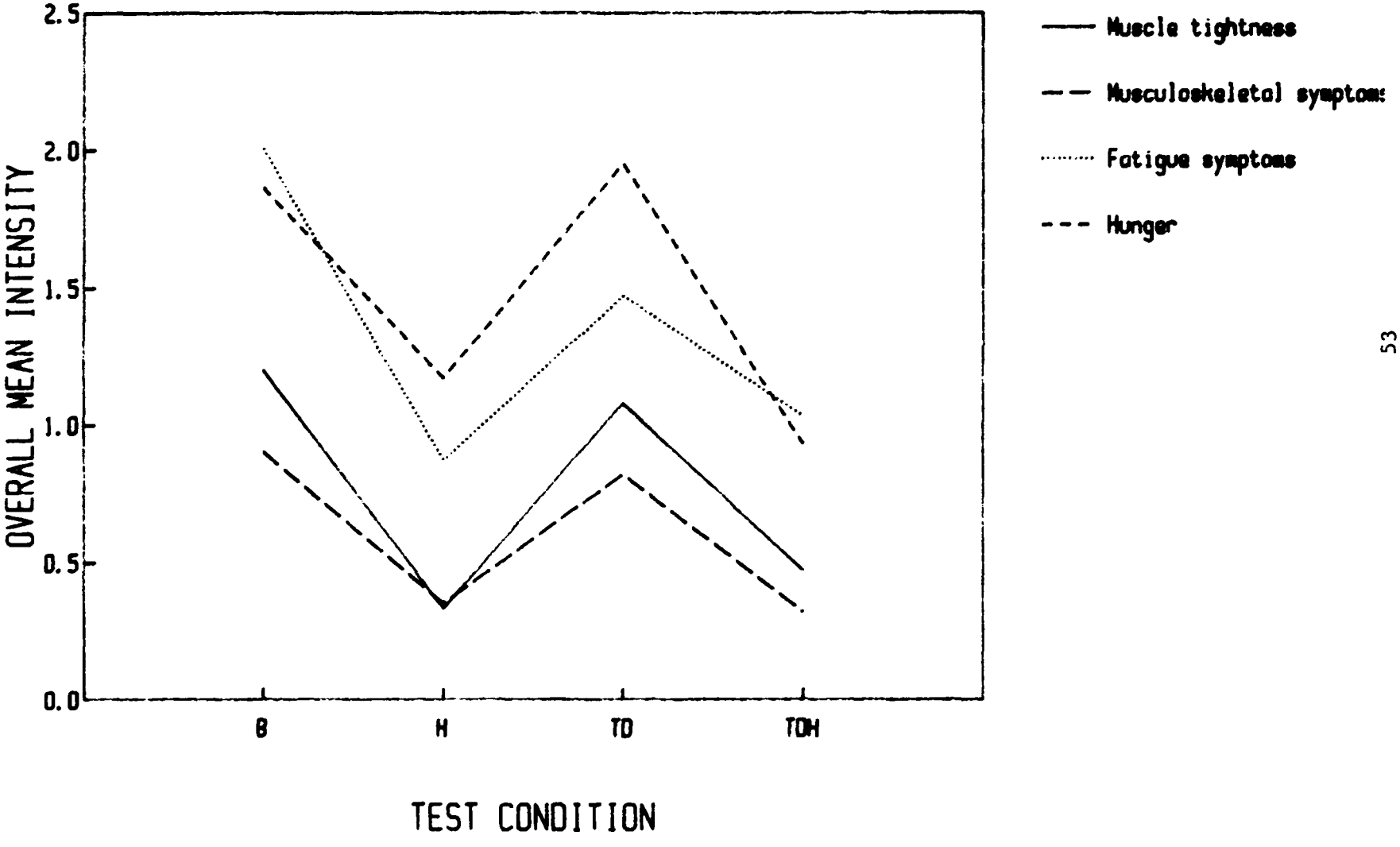


FIGURE 18. TEST CONDITION EFFECTS
Symptom Patterns: Casualties

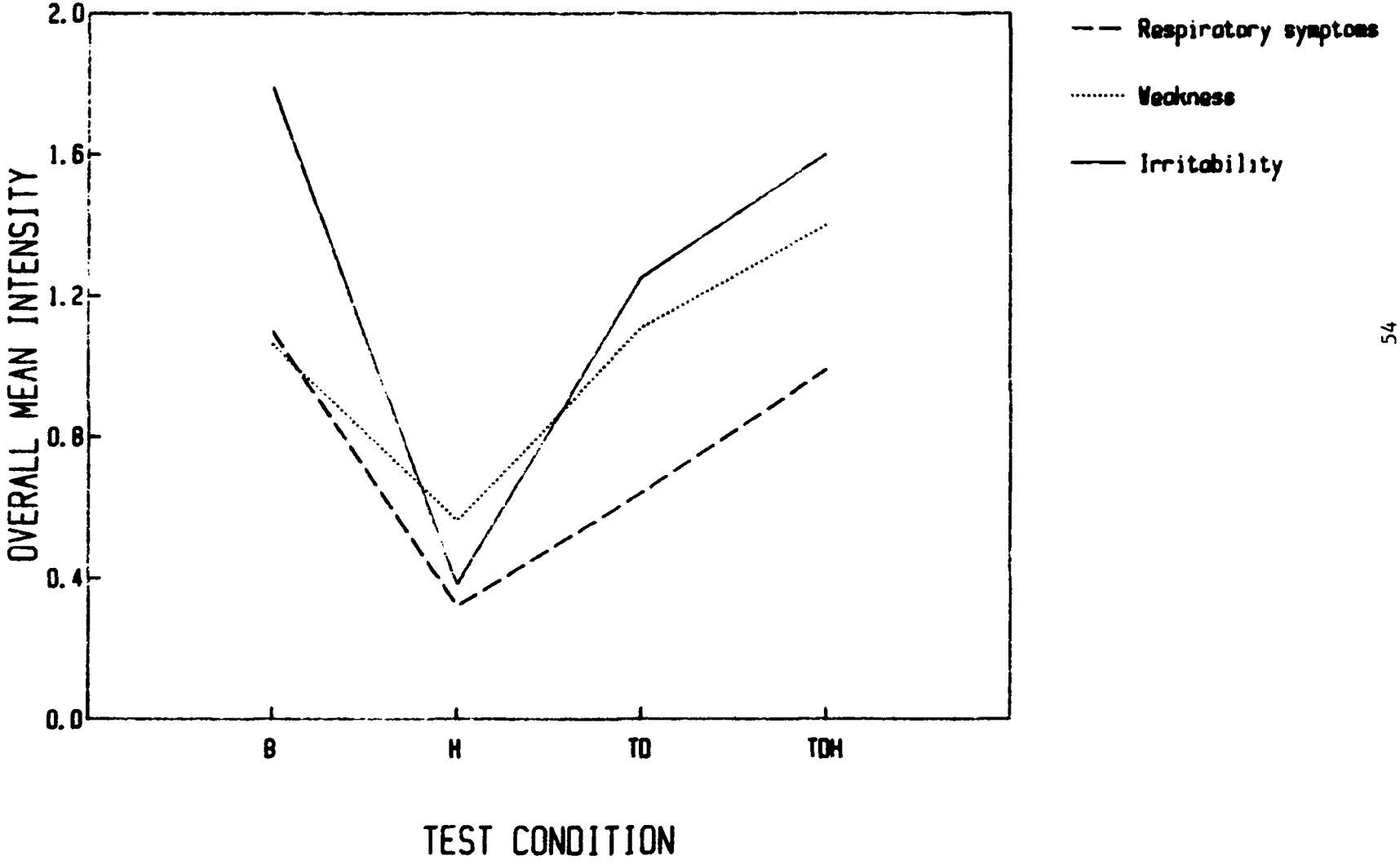


FIGURE 19. TEST CONDITION EFFECTS
Casualty Endurance Time

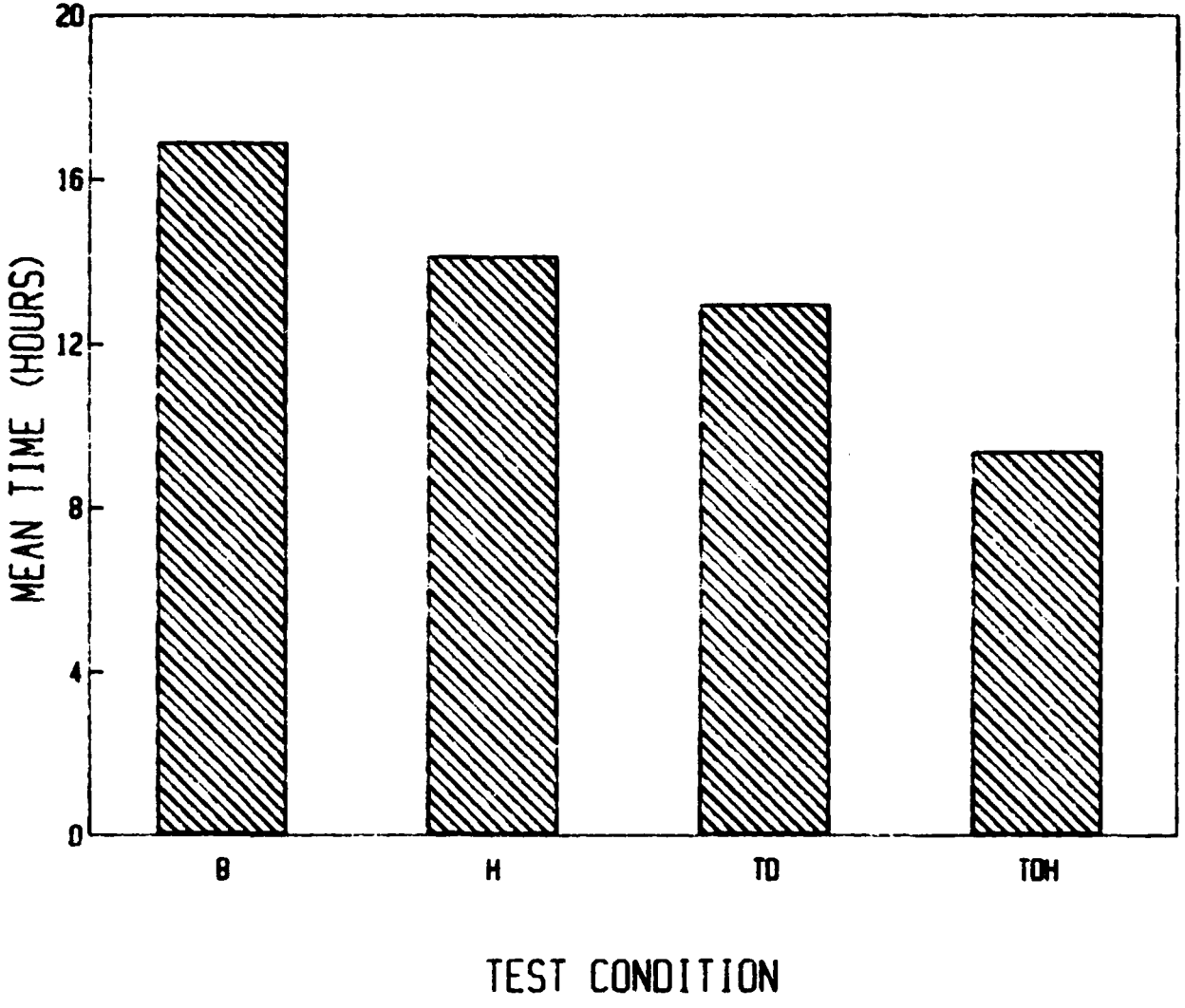


FIGURE 20. TEST CONDITION EFFECTS
Performance Measures

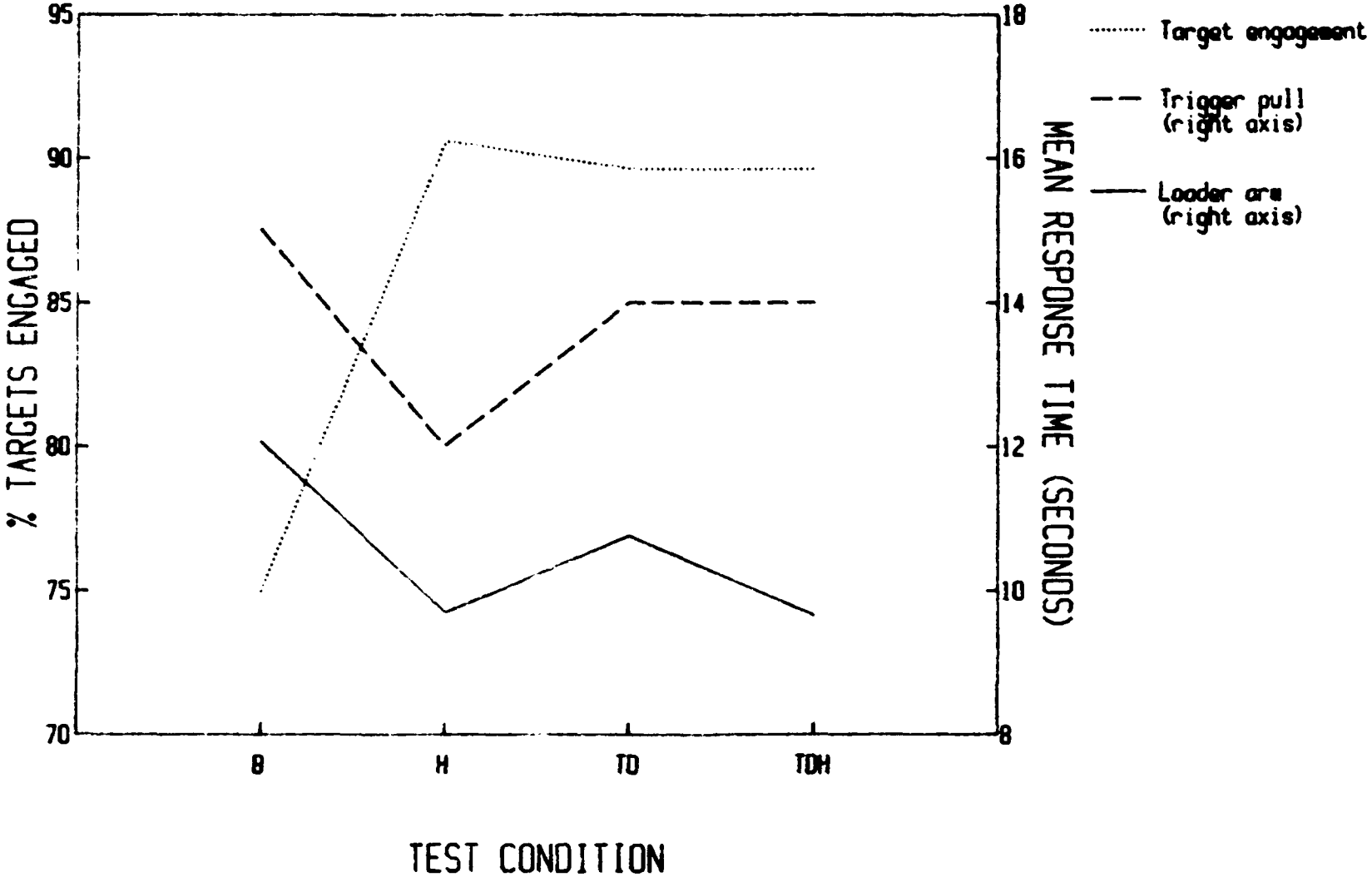


FIGURE 21. TEST CONDITION EFFECTS
Mood Pattern: All Crew Members

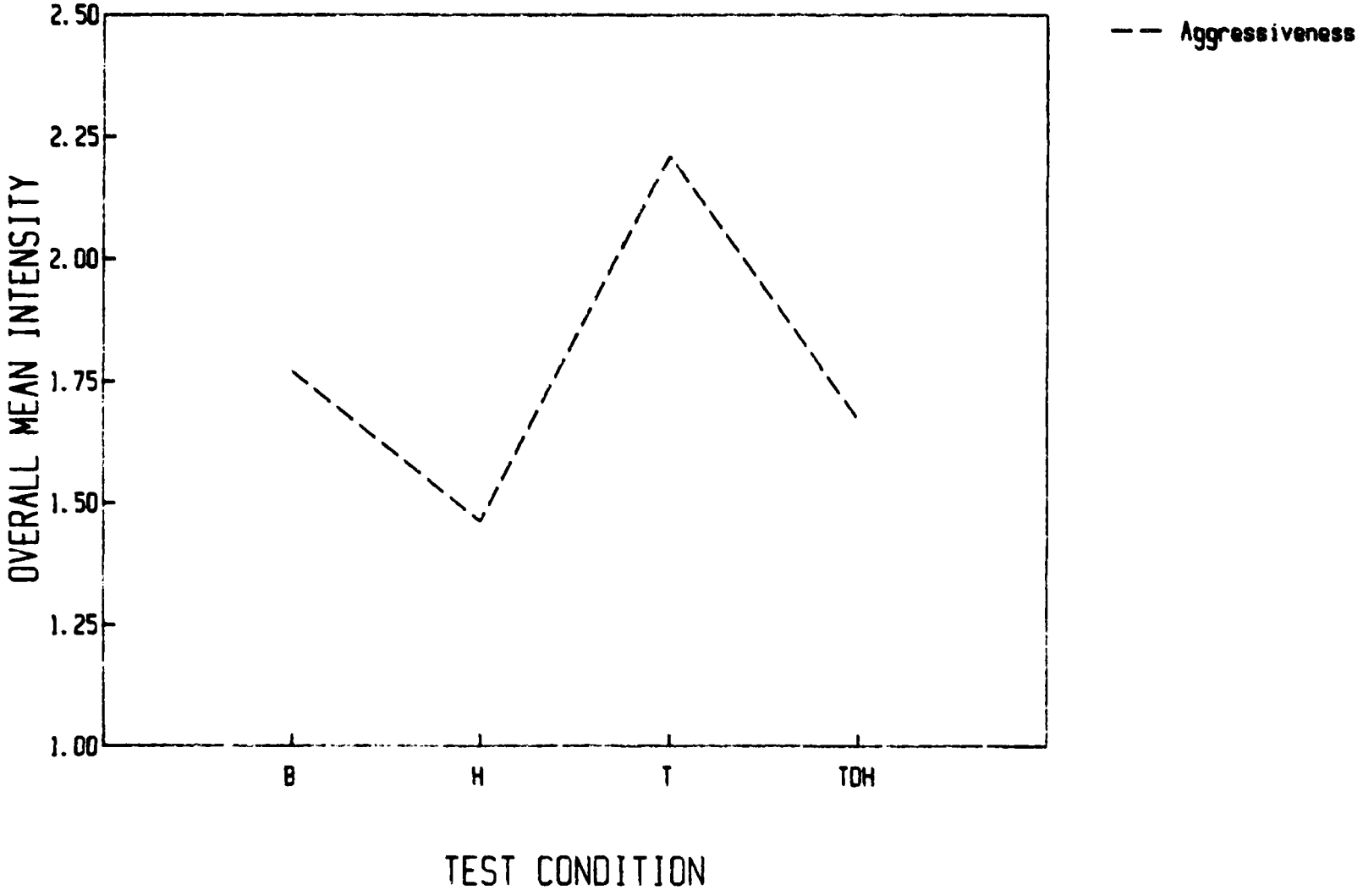


FIGURE 22. TEST CONDITION EFFECTS
Mood Patterns: Casualties

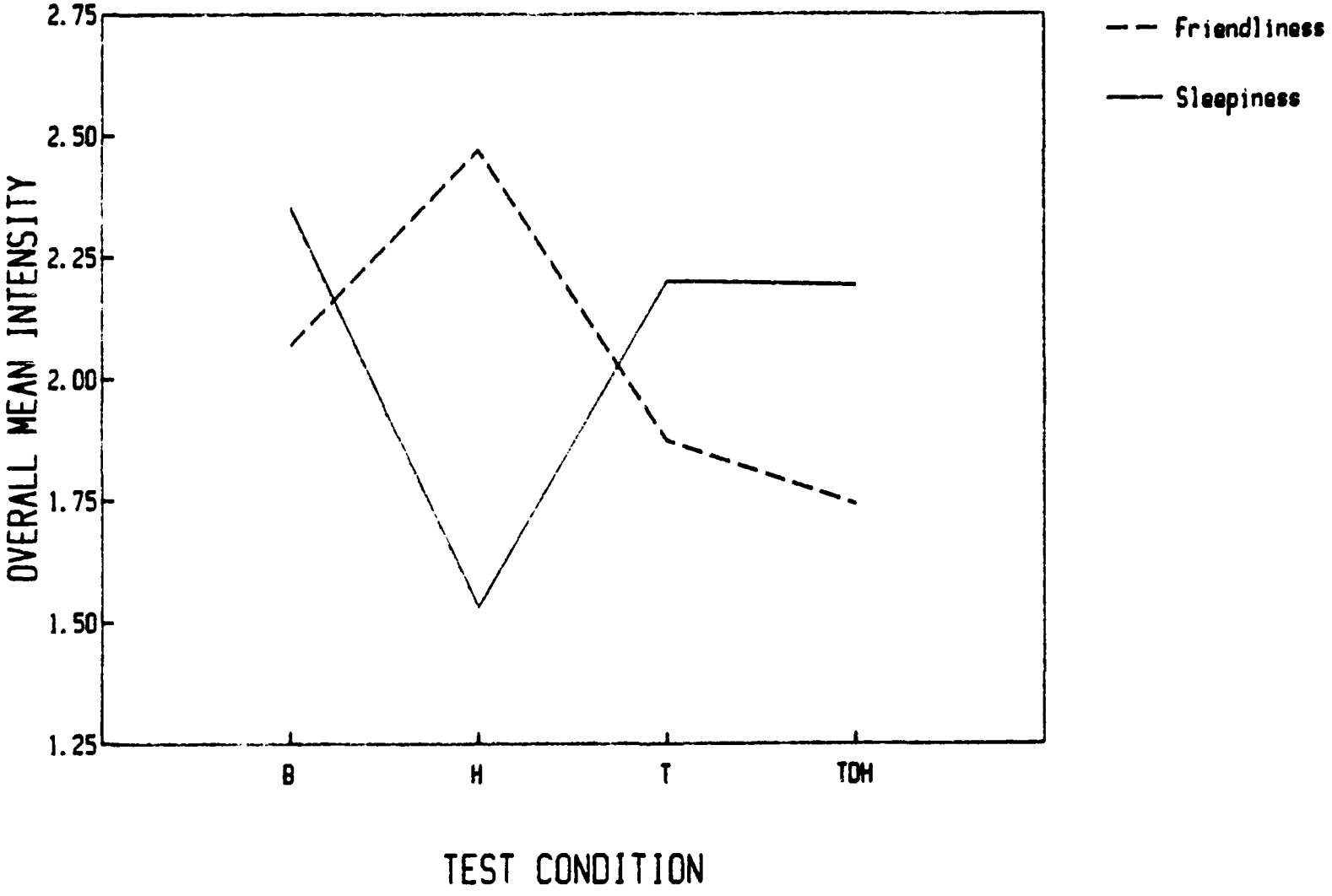
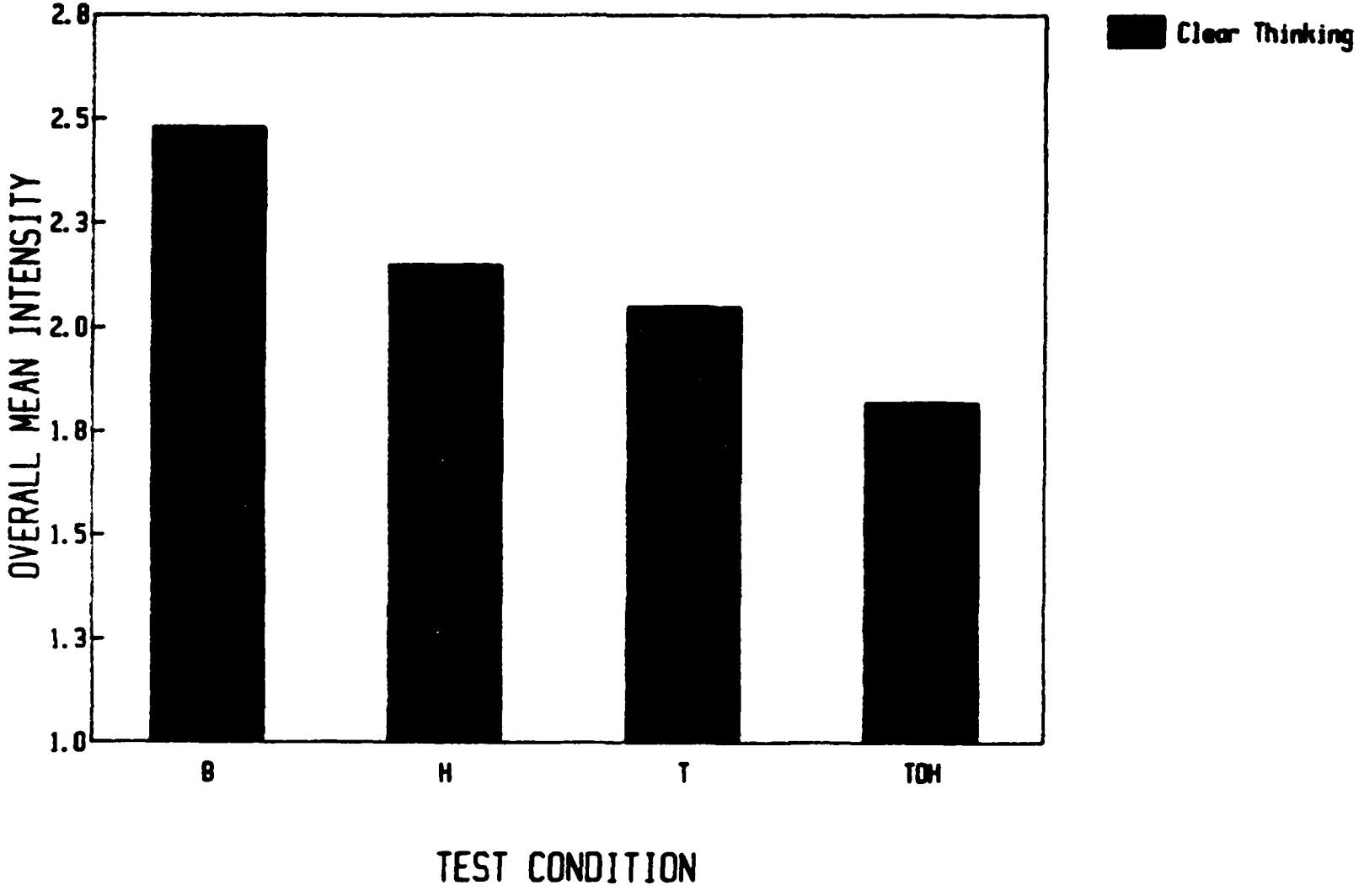


FIGURE 23. TEST CONDITION EFFECTS
Mood Pattern: Casualties



APPENDIX A. NBC STRESS MANAGEMENT. Topics and examples of techniques used in individual sessions with four-man crews

TOPIC	SUBTOPIC	PRIMARY TECHNIQUE
	S E S S I O N O N E	
GENERAL STRATEGIES	predicition	information-seeking
	control	differential reinforcement
	escape	interpersonal diversion
	S E S S I O N T W O	
UNIT-LEVEL PROBLEMS	miscommunication	communication skills
	polarization	assertiveness skills
	S E S S I O N T H R E E	
INDIVIDUAL PROBLEMS	depression	cognitive restructuring
	S E S S I O N F O U R	
INDIVIDUAL PROBLEMS (continued)	anxiety	relaxation techniques
	low arousal	activation techniques

APPENDIX B. PSYCHOLOGICAL TESTS ADMINISTERED BEFORE AND DURING TEST

ADMINISTRATION TIME	TYPE OF TEST
TRAINING/ORIENTATION PERIOD	Demographic Survey
	Crew Duty Position Survey
	Problem-Solving Inventory
	Spielberger Trait Anxiety Scale
	Beck Depression Inventory
	Rotter Locus of Control Questionnaire
	Zuckerman Sensation Seeking Scale
PRE-, DURING, AND POST-TEST	Environmental Symptoms Questionnaire
	Clyde Mood Scale
	Crew Member Rating Scale
	Crew Atmosphere Scale
	Cognitive Strategies Questionnaire

APPENDIX C. CLASSIFICATION OF SYMPTOM AND MOOD ITEMS BY FACTORS

CLASSIFICATION OF SYMPTOM AND MOOD ITEMS BY FACTORS

ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE (ESQ)						
Respiratory Muscle cramps Painful breathing Shortness of breath Muscle tightness Stomach cramps Poor concentration Malaise Difficulty breathing Headache Difficulty sleeping Partial numbness **Mental** Alertness	**Fatigue** Sleepiness Tiredness Boredom Depression Thirst Restlessness Irritability	**Neurological** Dim vision Dizziness Faintness Lightheadedness Backache **Gastrointestinal** Nausea Poor coordination Stomach ache Gas Appetite loss	**Musculoskeletal** Arm/shoulder ache Leg/foot ache Weakness Nosebleed "Hangover"	**Thermal** General sweatiness Foot sweatiness Warmth Eye irritation Stuffy Nose		
CLYDE MOOD SCALE (CMS)						
Clear Thinking Efficient Alert Clear thinking Able to concentrate Independent Businesslike Hardworking Dependable Nagging Grouchy	**Sleepiness** Sleepy Drowsy Tired Fatigued **Unhappiness** Troubled Sad Downhearted Worried Depressed Afraid Unhappy Lonely	**Dizziness** Dizzy Nauseous Shaky Jittery			**Friendliness** Pleasant Goodnatured Warmhearted Kind Humorous Playful Friendly Sociable Polite Considerate Impulsive Reckless	**Aggressiveness** Forceful Boastful Rude Sarcastic Sassy Bold Demanding Daring Quarrelsome Defiant Impulsive Reckless

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